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Assessment of Potential Environmental Problems Concerning Water Availability

Culp/Wesner/Culp, Santa Ana, CA

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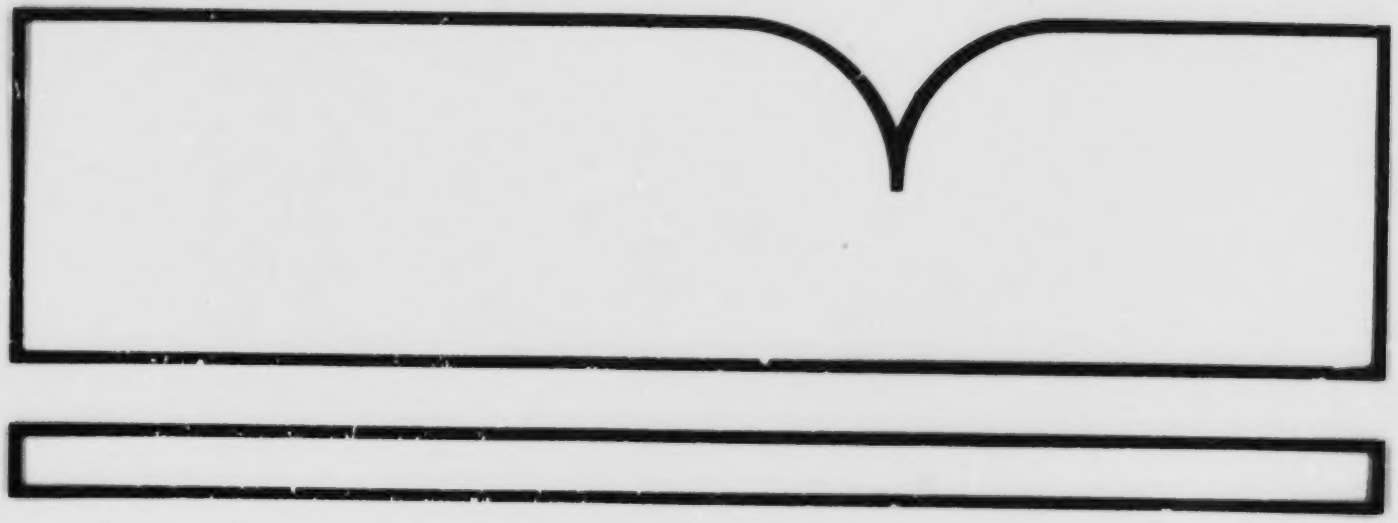

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ASSESSMENT OF POTENTIAL ENVIRONMENTAL PROBLEMS CONCERNING WATER AVAILABILITY

by

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16. ABSTRACT This study analyzes national supply and demand and summarizes data on all water resources regions. Estimates of the potential for wastewater reuse and recycling are also presented. The technology for improving the water supply through augmentation and conservation is reviewed, and the most feasible implementation methods are discussed in detail. Three detailed studies of water sensitive regions presented in this report illustrate the regional nature of the issues, problems, and research needs. The areas are San Antonio, Texas, South Coastal area of Southern California, and the Yadkin-Pee Dee Basin in North Carolina and South Carolina.

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EXECUTIVE SUMMARY

This study summarizes water supply and demand data for all water resources regions in the Nation, reviews the technology for water supply augmentation, presents evaluations of water resources in three widely different areas of the Nation, and analyzes issues, problems and research needs in water availability. Critical water problems facing the Nation include inadequate surface water supply and overdraft of ground water. There are other water related problems and potential problems in the Nation including pollution of surface and ground waters but the major concern is the inadequate, or marginally adequate, supply in many areas.

Agricultural irrigation is the largest current water user in the Nation and its percentage of total water use is projected to increase by the year 2000.

	Percent of Total Fresh Water Requirement	
	1975	2000
Agriculture	50.9	54.5
Steam Electric Power Plants	24.6	24.2
Manufacturing Industries	14.1	6.0
Domestic and Commercial	8.0	11.2
Minerals Industries	1.9	3.4
Other	0.5	0.7

Most of the agricultural use is in the Pacific Northwest, California, and Missouri regions. Cooling water for steam electric generating plants is the second largest requirement for fresh water with most of the demand in the Eastern States. Decreases projected in fresh water requirements for the steam electric and manufacturing industries are the results of projected increases in water recycling. It is estimated that fresh water supplied to manufacturing industries in the year 2000 will be used over 17 times and fresh water will be recycled over seven times by steam electric plants before it is discharged.

The two general methods of increasing the water supply are: (1) augmentation by increasing the quantity of water available to the user, and (2) conservation to reduce withdrawals and consumption. The following augmentation and conservation measures are evaluated in this study.

- Augmentation

  1. Desalination
  2. Wastewater recycling and reuse
  3. Brackish-saline water use
  4. Transfer and storage
  5. Evaporation reduction
  6. Vegetation management
  7. Weather modification
  8. Water rights
  9. Icebergs

- Conservation

  1. Agricultural irrigation efficiency
  2. Crop switching
  3. Cooling water techniques
  4. Domestic and commercial conservation devices

It is concluded that conservation, wastewater recycling and reuse, desalination and improved conjunctive use of ground water and surface water supplies offer the most immediate potential for increasing water supplies on a nationwide basis. Other methods may be used in more localized areas and others may be more widely used after further research and development. The water supply situation in the following three water sensitive regions is evaluated in detail in this study.

- San Antonio, Texas. Ground water is presently the sole source of water supply for the urban sections in a five county area of South Central Texas that includes the City of San Antonio.

- South Coastal California. About two-thirds of the water supplies for this 11,000 square mile area in Southern California are imported from the Colorado River and Northern California with the other one-third supplied from ground water and local runoff.

- Yadkin-Pee Dee River Basin. Surface water and ground water from within this river basin are the source of supply for an 18,000 square mile area in North Carolina and South Carolina.

Information on major issues, trends and research needs in water availability for this study were collected from several sources including:

1. Recent reports and review on the National water situation including comments and critiques on Federal water policy and research activities.

2. Regional reports, many of which were prepared under the Federal Water Resources Planning Act.

3. Reports by various State agencies.

4. Discussions with local water agency personnel and others during the work on this project.

5. Informal discussions with knowledgeable persons in Washington, D.C. to solicit opinions on major issues, trends and research needs in water availability.

It is concluded that many of the problems and issues are regional in nature. The issues that exist in all regions of the Nation are limited or inadequate water supply and concern for water quality. Inadequate or marginally adequate water supply is a problem in many areas especially in the Western States. The unresolved question of water rights on Indian lands and Federal lands limits the allocation of existing water supplies in many areas in the West.

At the present time the most feasible methods of augmenting water supplies are conservation, wastewater reuse and conjunctive use of ground and surface water supplies. Research needs are also somewhat regionalized in nature. The most immediate research needs are those that will advance the most feasible means of augmenting supplies: conservation, wastewater reuse, water rights and institutional arrangements.

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SECTION 1

INTRODUCTION

The Second National Assessment prepared by the U.S. Water Resources Council and numerous basin plans and reports describe problems of inadequate surface water supply and overdraft of ground water. Localized problems of inadequate supply exist in all regions of the Nation. Extensive ground water overdraft occurs in many areas.

This study reviews the National water supply and demand situation and summarizes data on all water resources regions. Estimates of the potential for wastewater reuse and recycle are also presented. The technology for improving the water supply through augmentation and conservation is reviewed and the most feasible methods are discussed in some detail.

Water supply problems and issues in the United States tend to be regional in nature and this is illustrated by a detailed description of water resources in three widely different areas: San Antonio, Texas, South Coastal area of Southern California, and the Yadkin-Pee Dee Basin in North Carolina and South Carolina.

This study focuses on the issues, problems and research needs in water availability. The National and Regional problems, issues and research needs are discussed along with the potential methods of increasing supplies.

SECTION 2

CHARACTERIZATION OF THE NATIONAL WATER SUPPLY AND DEMAND

This section presents a summary of information on water supplies and uses for the Nation based on data published by the U.S. Water Resources Council in the Second National Water Assessment.[1] The Second National Water Assessment provides information on 21 water resources regions and 106 subregions. The 21 regions are shown in Figure 1 and the regions and subregions are listed in Table 1. The regions are either the drainage area of a major river, a large segment of a major river, or the combined area of a series of rivers. The 21 regions are divided into 106 subregions, which are smaller drainage areas within the regions. The subregion is the basic information collection subdivision used for the Second National Water Assessment.

Information in the assessment is organized in three basic time periods - 1975, 1985 and 2000 - for both average and dry year conditions. The assessment presents different estimates for agricultural irrigation and steam electric water uses based on precipitation and stream flow. Dry conditions are defined as a moderate drought that occurs on the average of one year in five.

Information is summarized herein for withdrawals, consumption and wastewater discharges.

- o Withdrawals - fresh water taken from a surface water or ground water source and conveyed to the place of use.
- o Consumption - that part of the water withdrawn that is evaporated, transpired, incorporated into products and crops, consumed by humans or livestock, or otherwise removed from the immediate water supply.
- o Wastewater Discharges - water that is withdrawn and not consumed must eventually be discharged. Most steam electric plants and many manufacturing industries use water several times before it is discharged while most agriculture, commercial and domestic users discharge after one use.

Fresh water withdrawals, consumption and wastewater discharges for each of the 21 water resources regions are given in Table 2 and total functional water uses for all 21 regions are in Table 3. Missouri, California and Pacific Northwest are the highest water using regions and agricultural irrigation and steam electric power generation are the largest functional uses. Total projected fresh water withdrawals in the year 2000 under dry conditions are illustrated in Figure 2 and the following tabulation summarizes total fresh

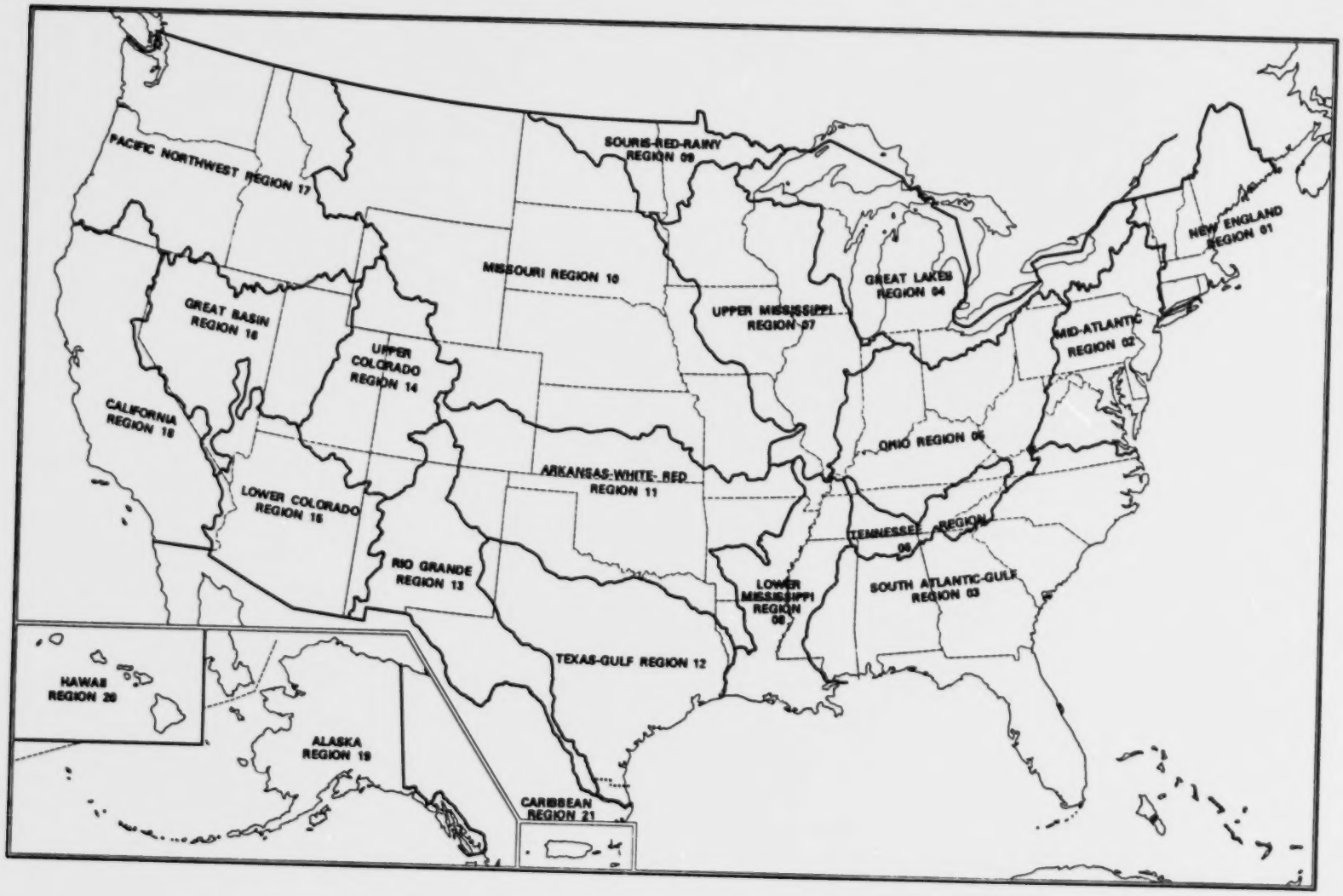

Figure 1. Water Resources Regions

TABLE 1

WATER RESOURCE COUNCIL REGIONS AND SUBREGIONS

Region Number	Subregion Number	Region	Subregion
1		NEW ENGLAND	
	101		Northern Maine
	102		Saco-Merrimack
	103		Mass-Rhode Island Coastal
	104		Housatonic-Thames
	105		Connecticut River
	106		Richelieu
		MID ATLANTIC	
2	201		Upper Hudson
	202		Lower Hudson-LI-N. New Jers
	203		Delaware
	204		Susquehanna
	205		Upper and Lower Chesapeake
	206		Potomac
3		SOUTH ATLANTIC GULF	
	301		Roanoke-Cape Fear
	302		Pee Dee-Edisto
	303		Savannah-St. Marys
	304		St. Johns - Suwannee
	305		Southern Florida
	306		Apalachicola
	307		Alabama-Choctawhatchee
	308		Mobil-Tombigbee
	309		Pascagoula-Pearl
4		GREAT LAKES	
	401		Lake Superior
	402		NW Lake Michigan
	403		SW Lake Michigan
	404		Eastern Lake Michigan
	405		Lake Huron
	406		St. Clair-Western Lake Erie
	407		Eastern Lake Erie
	408		Lake Ontario
5		OHIO	
	501		Ohio Headwaters
	502		Upper Ohio-Big Sandy
	503		Muskingum-Scioto-Miami
	504		Kanawha
	505		Kentucky-Licking-Green-Ohio
	506		Wabash
	507		Cumberland
6		TENNESSEE	
	601		Upper Tennessee
	602		Lower Tennessee
7		UPPER MISSISSIPPI	
	701		Mississippi Headwaters
	702		Black-Root-Chippewa-Wisc.
	703		Rock-Mississippi-Des Moines
	704		Salt-Sny-Illinois
	705		Lower Upper Mississippi
8		LOWER MISSISSIPPI	
	801		Hatchie-Miss-St. Francis
	802		Yazoo-Mississippi-Ouachita
	803		Mississippi Delta
9		SOURIS-RED-RAINY	
	901		Souris-Red-Rainy
10		MISSOURI	
	1001		Missouri-Milk-Saskatchewan
	1002		Missouri-Marias
	1003		Missouri-Musselshell
	1004		Yellowstone
	1005		Western Dakotas
	1006		Eastern Dakotas
	1007		North & South Platte
	1008		Niobrara-Platte-Loup
	1009		Middle Missouri
	1010		Kansas
	1011		Lower Missouri
11		ARKANSAS-WHITE-RED	
	1101		Upper White
	1102		Upper Arkansas
	1103		Arkansas-Cimarron
	1104		Lower Arkansas
	1105		Canadian
	1106		Red-Washita
	1107		Red-Sulphur
12		TEXAS-GULF	
	1201		Sabine-Neches
	1202		Trinity-Galveston Bay
	1203		Brazos
	1204		Colorado (Texas)
	1205		Neuces-Texas Coastal
13		RIO GRANDE	
	1301		Rio Grande Headwaters
	1302		Middle Rio Grande
	1303		Rio Grande-Pecos
	1304		Upper Pecos
	1305		Lower Rio Grande
14		UPPER COLORADO	
	1401		Green-White-Yampa
	1402		Colorado-Gunnison
	1403		Colorado-San Juan
15		LOWER COLORADO	
	1501		Little Colorado
	1502		Lower Colorado Main Stem
	1503		Gila
16		GREAT BASIN	
	1601		Bear-Great Salt Lake
	1602		Sevier Lake
	1603		Humboldt-Tonopah Desert
	1604		Central Lahontan
17		PACIFIC NORTHWEST	
	1701		Clark Fork-Kootenai
	1702		Upper/Middle Columbia
	1703		Upper/Central Snake
	1704		Lower Snake
	1705		Coast-Lower Columbia
	1706		Puget Sound
	1707		Oregon Closed Basin
18		CALIFORNIA	
	1801		Klamath-North Coastal
	1802		Sacramento-Lahontan
	1803		San Joaquin-Tulare
	1804		San Francisco Bay
	1805		Central CA Coast
	1806		Southern California
	1807		Lahontan-South
19		ALASKA	
	1901		Alaska
20		HAWAII	
	2001		Hawaii County
	2002		Maui County
	2003		Honolulu County
	2004		Kauai County
21		CARIBBEAN	
	2101		Puerto Rico
	2102		Virgin Islands

TABLE 2

REGIONAL FRESH WATER WITHDRAWALS, CONSUMPTION

AND WASTEWATER DISCHARGES - 1975, 1985, 2000

(million gallons per day)

Water Resources Region	Withdrawals			Consumption			Wastewater Discharges		
	1975	1985	2000	1975	1985	2000	1975	1985	2000
1 - New England	5,098	3,939	3,230	481	647	1,063	4,617	3,292	2,167
2 - Mid-Atlantic	18,300	15,857	13,873	1,843	2,472	3,548	16,457	13,385	10,325
3 - South Atlantic-Gulf	24,510	25,457	28,340	4,867	6,772	10,053	19,643	18,685	18,287
4 - Great Lakes	42,813	32,666	25,623	2,598	3,300	4,693	40,215	29,366	20,930
5 - Ohio	34,934	27,838	16,925	1,798	2,527	4,332	33,136	25,311	12,593
6 - Tennessee	7,412	7,131	6,013	313	647	1,105	7,099	6,484	4,908
7 - Upper Mississippi	12,401	10,386	7,910	1,145	1,604	2,688	11,256	8,782	5,222
8 - Lower Mississippi	14,567	17,453	24,841	4,027	4,554	5,511	10,540	12,899	19,330
9 - Souris-Red-Rainy	336	329	587	112	204	446	224	125	141
10 - Missouri	38,016	48,037	44,359	15,469	19,206	19,913	22,547	28,831	24,446
11 - Arkansas-White-Red	12,868	13,799	13,337	8,064	8,769	8,887	4,804	5,030	4,450
12 - Texas-Gulf	16,925	15,932	14,991	11,259	10,227	10,529	5,666	5,705	4,462
13 - Rio Grande	6,321	6,204	5,633	4,240	4,320	4,016	2,081	1,884	1,617
14 - Upper Colorado	6,869	7,841	7,519	2,440	3,018	3,232	4,429	4,823	4,287
15 - Lower Colorado	8,917	8,528	7,857	4,595	4,754	4,708	4,322	3,774	3,149
16 - Great Basin	7,991	7,316	7,258	3,779	3,765	4,036	4,212	3,551	3,222
17 - Pacific Northwest	37,495	38,098	33,852	11,913	14,610	15,196	25,582	23,488	18,656
18 - California	39,636	40,549	41,265	26,641	27,932	29,699	12,995	12,617	11,566
Totals 1 - 18	335,409	327,360	303,413	105,584	119,328	133,655	229,825	208,032	169,758
19 - Alaska	305	433	745	58	207	459	247	226	286
20 - Hawaii	1,879	1,619	1,349	605	636	666	1,274	983	683
21 - Caribbean	907	963	890	343	374	300	564	589	590
Totals 1 - 21	338,500	330,375	306,397	106,590	120,545	135,080	231,910	209,830	171,317

TABLE 3

FUNCTIONAL FRESH WATER USE IN ALL
21 WATER RESOURCES REGIONS
(million gallons per day)

Functional Use	Withdrawals			Consumption			Wastewater Discharges		
	1975	1985	2000	1975	1985	2000	1975	1985	2000
Domestic									
Central (municipal)	21,164	23,983	27,918	4,976	5,665	6,638	16,188	18,318	21,280
Noncentral (rural)	2,092	2,320	2,400	1,292	1,408	1,436	800	912	964
Commercial	5,530	6,048	6,732	1,109	1,216	1,369	4,421	4,832	5,363
Manufacturing	51,222	23,687	19,669	6,059	8,903	14,699	45,163	14,784	4,970
Agriculture									
Irrigation	158,743	166,252	153,846	86,391	92,820	92,506	72,352	73,432	61,340
	(182,802)	(192,142)	(177,760)	(98,062)	(105,899)	(105,778)	(84,740)	(86,243)	(71,982)
Livestock	1,912	2,233	2,551	1,912	2,233	2,551	0	0	0
Steam electric generation	88,916	94,858	79,492	1,419	4,062	10,541	87,497	90,796	68,951
	(89,099)	(94,945)	(80,144)	(1,440)	(4,112)	(10,603)	(87,659)	(90,833)	(69,541)
Minerals industry	7,055	8,832	11,328	2,196	2,777	3,609	4,859	6,055	7,719
Public lands and others	1,866	2,162	2,461	1,236	1,461	1,731	630	701	730
Total fresh water	338,500	330,375	306,397	106,590	120,545	135,080	231,910	209,830	171,317
	(362,742)	(356,352)	(330,963)	(118,282)	(133,674)	(148,414)	(244,460)	(222,678)	(182,549)

NOTE: Figures are for normal rainfall and stream flow except those in parentheses which are for dry years. Withdrawals and consumption are higher in dry years for agricultural irrigation and steam electric generation uses.

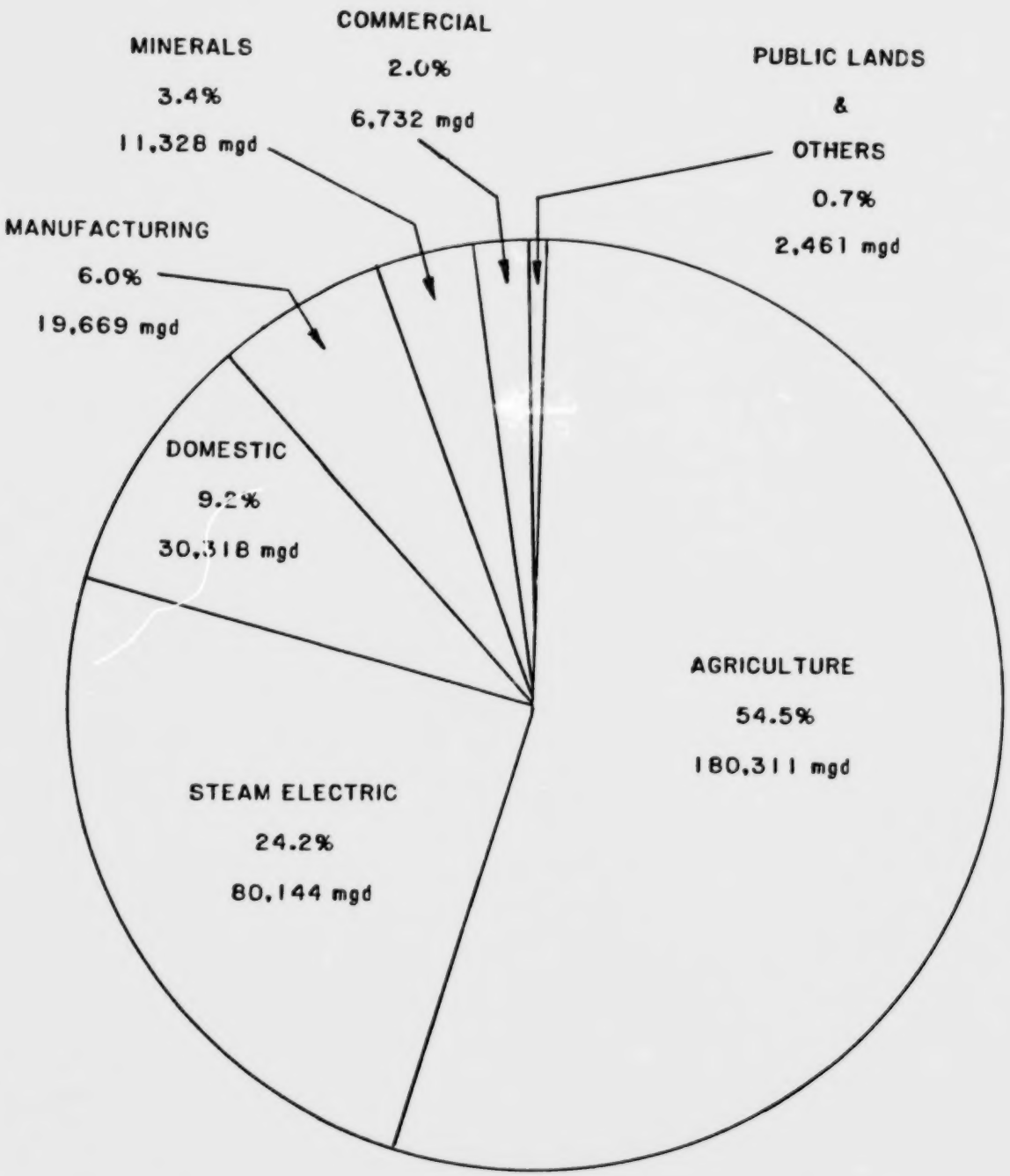

Figure 2. Projected National Fresh Water Withdrawals in the Year 2000 Under Dry Conditions

water withdrawals and wastewater discharges in billion gallons per day (bgd) for 1975 and 2000.

	Water Withdrawal			Wastewater Discharge		
	Quantity, bgd		Percent Change	Quantity, bgd		Percent Change
	1975	2000	1975-2000	1975	2000	1975-2000
Agriculture	184.7	180.3	- 2	84.7	72.0	- 5
Steam Electric	89.1	80.1	- 10	87.7	69.5	- 21
Manufacturing	51.2	19.7	- 62	45.2	5.0	- 89
Domestic & Commercial	128.8	37.1	+ 29	21.4	27.6	+ 29
Minerals	7.1	11.3	+ 59	4.9	7.7	+ 57
Other	1.8	2.5	+ 33	0.6	0.7	+ 17
TOTALS	362.7	331.0	- 9	244.5	182.5	- 25

These data show that fresh water requirements, as represented by withdrawals, for agriculture and steam electric plant cooling decrease somewhat (2 and 10 percent respectively). Manufacturing requirements are estimated to decrease by over 60 percent by the year 2000 and requirements for municipal (domestic and commercial) purposes and minerals industries are projected to increase. Wastewater discharges from agriculture, steam electric plants and manufacturing industries are estimated to decrease by the year 2000 and discharges from municipalities and minerals industries are estimated to increase.

It is estimated that agriculture and steam electric plants will continue to use over 75 percent of all fresh water withdrawn in the United States.

	Percent of Total Fresh Water Requirement	
	1975	2000
Agriculture	50.9	54.5
Steam Electric Power Plants	24.6	24.2
Manufacturing Industries	14.1	6.0
Domestic and Commercial	8.0	11.2
Minerals Industries	1.9	3.4
Other	0.5	0.7

About 99 percent of agricultural water use is for irrigation. Agricultural irrigation is the largest current, and projected future, water user in the Nation. Most of the demand (63 percent of National total) for agricultural water is in the Pacific Northwest, California and Missouri regions.

Cooling water for steam electric generating plants represents the second largest requirement for fresh water in the Nation (89 bgd in 1975 and 80 bgd in 2000). Most of the demand is in the Eastern United States with the Great Lakes and Ohio regions accounting for over 50 percent of the total national requirement. The large decreases projected in fresh water requirements and wastewater discharges for the steam electric and manufacturing industries are the result of large projected increases in water recycling. Recycling in manufacturing industries and steam electric plants is projected to increase substantially by the year 2000 as shown in the following summary:

	Fresh Water Recycled, bgd		Recycle Rate	
	1975	2000	1975	2000
Steam Electric	57	517	1.6	7.5
Manufacturing Industries	61	316	2.2	17.1
Minerals Industries	21	32	4.0	4.0
TOTALS	139	865	1.9	8.8

As shown above, it is estimated that fresh water supplied to manufacturing industries in the year 2000 will be used over 17 times before it is discharged. This recycling by manufacturing industries results in a 62 percent decrease in the amount of fresh water required by 2000 and decreases the requirement for manufacturing from about 14 percent of the National total in 1975 to 6 percent in the year 2000.

A breakdown of fresh water withdrawals from surface water and ground water sources is given in Table 4. The amount of ground water overdraft and the subregions in which overdraft occurs are also shown in this table.

TABLE 4

SOURCE OF FRESH WATER WITHDRAWALS - 1975

Water Resources Region	Withdrawals (mgd)			Average Stream Flow (bgd)	Groundwater Overdraft (mgd)	Subregions	
	Surface	Ground	Total			Number in Region	Number with Overdraft
1 - New England	4,463	635	5,098	78.2	0	6	0
2 - Mid-Atlantic	15,639	2,661	18,300	79.2	32	6	3
3 - South Atlantic-Gulf	19,061	5,449	24,510	228.0	339	9	8
4 - Great Lakes	41,598	1,215	42,813	72.7	27	8	1
5 - Ohio	33,091	1,843	34,934	(178.0)*	0	7	0
6 - Tennessee	7,141	271	7,412	(40.8)	0	2	0
7 - Upper Mississippi	10,035	2,366	12,401	(121.0)	0	5	0
8 - Lower Mississippi	9,729	4,838	14,567	433.0	412	3	3
9 - Souris-Red-Rainy	250	86	336	6.0	0	1	0
10 - Missouri	27,609	10,407	38,016	(44.1)	2,557	11	10
11 - Arkansas-White-Red	4,022	8,846	12,868	(62.6)	5,457	7	7
12 - Texas-Gulf	9,703	7,222	16,925	28.3	5,578	5	5
13 - Rio Grande	3,986	2,335	6,231	1.2	657	5	4
14 - Upper Colorado	6,743	126	6,869	(10.0)	0	3	0
15 - Lower Colorado	3,909	5,008	8,917	1.6	2,415	3	3
16 - Great Basin	6,567	1,424	7,991	2.6	591	4	4
17 - Pacific Northwest	30,147	7,348	37,495	255.3	627	7	6
18 - California	20,476	19,160	39,636	47.4	2,197	7	5
Totals 1 - 18	254,169	81,240	335,409	1,233.4	20,889	99	59
19 - Alaska	261	44	305	905.0	0	1	0
20 - Hawaii	1,089	790	1,879	6.7	0	4	0
21 - Caribbean	653	254	907	4.9	13	2	1
Totals 1 - 21	256,172	82,328	338,500	2,150.0	20,902	106	60

*Stream flows in parentheses are not included in total because they are inflows to another region.

SECTION 3

METHODOLOGY FOR SUPPLEMENTING NATIONAL WATER SUPPLIES

Critical water problems identified in the Second National Assessment include inadequate surface water supply and overdraft of ground water.[1] Localized problems of inadequate surface water supply were identified in all 21 water resources regions with 17 subregions expected to have serious problems by the year 2000. Extensive ground water overdraft is occurring in 8 of the 106 subregions and 60 subregions are experiencing some overdraft. There are other water related problems and potential problems in the Nation including pollution of surface and ground waters, flooding and erosion; however, the overriding concern is the inadequate, or marginally adequate, supply in many areas.

The two general methods of improving the water supply situation are: (1) augmentation by increasing the quantity of water available to the user, and (2) conservation to reduce withdrawals and consumption. The following augmentation and conservation measures are evaluated in this section.

- o Augmentation

  1. Desalination
  2. Wastewater recycling and reuse
  3. Brackish-saline water use
  4. Transfer, storage and management
  5. Conjunctive use
  6. Evaporation reduction
  7. Vegetation management
  8. Weather modification
  9. Water rights
  10. Icebergs

- o Conservation

  1. Agricultural irrigation efficiency
  2. Crop switching
  3. Cooling water techniques
  4. Domestic and commercial conservation devices

There is not a clear distinction between augmentation and conservation in some cases but the purpose here is to consider all feasible alternatives for increasing water supplies.

DESALINATION

Desalination techniques are currently in use on municipal and industrial water supplies and in some cases are used to process wastewater for reuse or discharge. Techniques currently in use to desalt brackish water include reverse osmosis, electrodialysis and ion exchange. Distillation processes are used in Mexico and several countries in the Middle East to produce fresh water from sea water. There are rather extensive installations of desalination systems for industrial water treatment in the United States that utilize ion exchange, electrodialysis, reverse osmosis, or sometimes a combination of two processes. Electrodialysis and reverse osmosis have also been used to treat municipal water supplies and reverse osmosis has been used in some special cases for wastewater treatment.

Electrodialysis was the first process to be fully developed for desalting brackish municipal water supplies, and there are at least six municipal plants in operation in the United States. The first electrodialysis plant in a municipal water supply system began operation in Buckeye, Arizona in 1962. The reverse osmosis process has been extensively developed in the last 15 years, and there are several municipal desalting plants in operation in the United States. The ion exchange process has been used for many years in the United States for softening municipal water supplies, and there are several large plants which have operated successfully. All three of these processes have also been used for many years to treat industrial water supplies, in some cases producing extremely high quality water for specialized manufacturing purposes.

These desalination techniques are well developed and research is continuing to improve the performance and reliability of the methods. The disadvantages are their relatively high costs and energy requirements. Another important factor that must be considered in operation of any of these processes is brine disposal. All desalting techniques produce a waste brine, that requires treatment in some cases, for ultimate disposal.

In June, 1980, there were about 2,200 desalting plants with a capacity of 25,000 gallons per day or larger in operation, or under costruction, throughout the world. The total capacity of all these plants was about two billion gallons per day. About 15 percent of this worldwide capacity is located in the United States.[2]

Desalination is a techniqually feasible alternative in any location with a supply of brackish or sea water, but cost of desalting is not competitive with alternative supplies in many locations. It is doubtful that desalting will ever be economically feasible to treat water for irrigation or steam electric cooling uses. However, desalting may be a cost competitive water source for industrial and municipal applications in some locations.

WASTEWATER RECYCLING AND REUSE

The terms "recycling" and "reuse" are often used interchangeably. However, it is important to make the distinction between these two terms because of the difference in magnitude of the quantities involved. The term

reuse is used for wastewaters that are discharged and then withdrawn by a user other than the discharger. Recycling is defined as the internal use of water by the original user prior to discharge.

Wastewaters that are being discharged and wasted are candidates for reuse. For example, much of the municipal wastewater from the cities along the coastlines of the Nation are used and then discharged to outfalls in the ocean. Similarly, there are substantial municipal discharges to large streams in the interior of the Nation that are not directly reused, or often not reused at all. These discharges present the potential for reuse thereby augmenting the fresh water supply.

There is a substantial potential for recycling of water by industry and steam electric generating plants. Any water that can be recycled will reduce the requirements for fresh water withdrawal.

Major water uses that could substitute reclaimed wastewater for fresh water include agricultural irrigation, landscape irrigation, steam electric cooling, industrial cooling and industrial process water. Reclaimed wastewater for municipal purposes, other than landscape irrigation, will not be an important factor in the forseeable future for two reasons (1) there are unresolved questions on the health aspects of using wastewater that will limit its potential for municipal use in the near future, and (2) the quantity of water required for portable purposes is small in comparison to other requirements.

It is estimated that reuse of wastewater could provide a significant increase in the water supply and that water recycling can make it possible to actually reduce total fresh water withdrawals. The following summary shows estimated recycling and reuse quantities.[3]

	Quantity (billion gallons per day)		
	1975	1985	2000
Total fresh water withdrawals	362.7	356.3	330.9
Water withdrawals capable of wastewater reuse	331.3	320.8	290.3
Wastewater discharges available for reuse	172.6	149.1	121.1
Wastewater recycle	139.1	386.7	865.5
Wastewater reuse	0.7	2.1	4.8

The estimated reuse in the year 2000 ranges from 1 mgd in the Souris-Red-Rainy and Alaska regions to 1,139 mgd in the Missouri region; reuse of 733 mgd and 696 mgd are estimated for the Lower Colorado and California regions respectively. Over 50 percent of the reuse in 2000 is projected to occur in the Missouri, Lower Colorado and California regions. Recycling and reuse projections for the Nation in the year 2000 are as follows:[3]

	Quantity (billion gallons per day)	
Water withdrawals capable of wastewater reuse		290.3
Agricultural Irrigation	177.8	
Landscape Irrigation	1.4	
Steam Electric	80.1	
Industrial Cooling	16.9	
Industrial - Other	14.1	
Treated wastewater discharges available for reuse		109.6
Steam Electric	69.5	
Industry	12.7	
Municipal	26.7	
Fish Hatcheries	0.7	
Untreated agricultural discharges		11.5
Wastewater reuse		4.8
Wastewater recycle		865.5

It is estimated that (1) wastewater reuse will increase from 0.2 percent of fresh water withdrawals, capable of using wastewater, in 1975 to 1.7 percent in 2000, and (2) reuse of available wastewater will increase from 0.4 percent in 1975 to 4 percent in 2000. Recycling in the steam electric, manufacturing and minerals industries is projected to increase to 865.5 bgd by the year 2000. It is therefore projected that recycling will continue to supply the bulk of the Nation's total requirements for fresh water and that total fresh water withdrawals will actually be reduced as a result of this increase in recycling.

Several factors will determine the quantity of wastewater that will actually be reused by the year 2000 including: (1) the geographical location of discharges and potential users, (2) the timing of wastewater discharges and the requirements of potential users, e.g., irrigation requirements vary with the season but municipal discharges are relatively constant throughout the year, and (3) the availability and cost of alternative supplies.

There are large regional differences in wastewater availability and reuse potential. In the Eastern States and Alaska the quantities of available wastewater discharges and the withdrawals capable of reuse are relatively in balance. In the Western States, the withdrawals greatly exceed the available wastewater. This difference is primarily due to agricultural irrigation requirements.

Some uses of wastewater may require more than conventional secondary treatment in specific locations. For example, some industrial uses may require clarification and filtration, nitrogen and phosphorus removal or desalting.

Additional treatment may be required in some cases for wastewater used for cooling. Also, local regulatory agencies may require higher levels of treatment for some applications such as irrigation of food crops and irrigation of parks, playgrounds and schools.

BRACKISH-SALINE WATER USE

The total dissolved solids concentration in sea water is in the range of 30,000 to 35,000 mg/l, whereas water considered to be of good quality for municipal purposes has a total dissolved solids concentration of less than 500 mg/l. Brackish water is generally considered to be in the 1,000 to 3,000 mg/l range. This more saline water is undesirable for almost all uses, and as the total dissolved solids concentration increases above 1,000 mg/l, it eventually becomes unusable for irrigation and most industrial and manufacturing purposes.

Possibilities for the use of saline water includes irrigation of salt resistant crops, cooling water, and industrial process water. Saline water has been proposed for some uses in the development of energy resources in the Western United States.

Sources of saline water include both surface water and ground water, and return flows from agricultural irrigation. It is estimated that there is about 400 million gallons per day of saline water available in the Colorado River Basin with a total dissolved solids concentration ranging from 1,700 mg/l to 20,000 mg/l.[4] The potentially recoverable ground water supply in New Mexico is about 20 billion acre-feet. Three billion of this total is fresh and 1.4 billion acre-feet are slightly saline, but usable for some forms of irrigation. About 15 billion acre-feet exceed total dissolved solids concentrations of 3,000 mg/l.

The Colorado River Basin Salinity Control Forum is considering industrial use of irrigation runoff in Grand Valley, Colorado. The Forum has also recommended that the U.S. Water and Power Resources Service consider encouraging the industrial use of saline water where cost-effective, as a joint private industry-government salinity control measure. A recent survey of New Mexico water users by the New Mexico Water Resources Research Institute revealed that most water users in New Mexico believe that research is needed on the utilization of the State's saline water resources. Several Federal agencies support research projects in developing salt and drought tolerant plants.

The U.S. Water Resources Council in the Second National Water Assessment estimated that total use of saline water in the Nation would increase from 59.7 billion gallons per day in 1975 to 119 billion gallons per day in the year 2000. Most of this use is for cooling in steam electric generation and manufacturing industries in coastal areas. There have been no detailed studies on the potential for use of saline water to augment fresh water supplies in inland areas of the Nation.

EVAPORATION REDUCTION

Evaporation losses in the Western and arid areas of the Nation are substantial. For example, the water loss by evaporation in the Las Vegas, Nevada area is about 8 feet per year. In all areas of New Mexico the annual evaporation exceeds precipitation, and, in some areas, evaporation exceeds precipitation by over 100 inches. Estimated evaporation losses in New Mexico in 1970 were about 214,000 acre-feet. Reservoir area is projected to increase in New Mexico by almost 100,000 acres by the year 2000, resulting in an increase in evaporation losses to about 400,000 acre feet per year.[4]

The University of Arizona's Water Resources Research Center, recently compared 13 alternatives for meeting future water requirements in Tucson. The report concluded that evaporation reduction may be the best alternative for meeting Tucson's future water requirements.[5]

Various techniques have been studied to reduce evaporation including spreading films on the water, placing floating objects in the water, minimizing the water surface, planting trees or other barriers to reduce wind, and destratification by pumping cooler water from lower levels in the reservoir to mix with warmer surface water.

Evaporation reduction offers the potential to increase the water supply in some water short areas of the Nation, but the technology is not well developed. There are no detailed studies on the potential for this method in augmenting the Nation's fresh water supplies.

WATER TRANSFER AND STORAGE AND MANAGEMENT

Transfer of water within basins (intra basins) and between basins (inter basin) are possible methods of increasing water supplies. Intra basin transfers may be possible in localized areas and potentially large sources are available through inter basin transfers. Alaska, Canada and the Pacific Northwest areas of the United States are potential sources of water for transfer.

There are a variety of political, environmental and economic obstacles to any inter basin transfer proposal. For example, transfer of water from the Columbia River Basin into the Upper Colorado River Basin was first proposed several years ago. Political opposition has been strong enough to prevent this project, and, in fact, the Colorado River Basin Project Act which was renewed in 1978 prohibits the Department of Interior from even carrying out any investigative studies of transfer from any other basins to the Colorado River Basin. Another example is the strong opposition to additional transfer of water in California from the Northern to the Southern part of the State.

Although there are potentially very large quantities of water that could be transferred from one area of the Nation or the Continent to another, it is doubtful that this alternative will be used to any extent by the year 2000.

Increasing surface water impoundments and ground water storage may offer the potential for increasing water supplies in some areas. However, surface reservoirs have already been constructed in almost all of the desirable

locations. New surface storage will be expensive to construct and political and environmental factors will make it difficult to find suitable sites.

Management of reservoirs may significantly increase reservoir yields. Relatively minor changes in operating procedures may increase yields by 10 to 20 percent in some reservoirs.

CONJUNCTIVE USE

Conjunctive utilization of surface and ground water reservoirs offers the potential for increasing the efficiency of using existing supplies in some areas. In conjunctive use, surface reservoirs impound streamflow which is then transferred at an optimum rate to ground water storage. Surface storage supplies most annual water requirements while ground water reservoirs, generally being many times larger, can be retained for use during dry periods. Ground water levels would be lowered during dry periods and raised during wet periods. The rate of transfer from surface to ground water storage must be large enough so that surface reservoirs will be drawn down enough to retain runoff from the next wet period.

Conjunctive use operations, and consideration of additional surface storage, are in progress in the water short areas of the Nation. Storage of reclaimed wastewater in ground water basins is being extensively evaluated in California. The principal value of ground water basins is that they are generally very large compared to surface water reservoirs and provide the potential for storage during normal, or above normal, periods of rainfall and runoff, for use during drought periods. For example, in the Central Valley of California the total ground water storage capacity is estimated to be 130,000,000 acre-feet or more than four times the 30,000,000 acre-feet of surface storage planned in the entire Central Valley Project.

VEGETATION MANAGEMENT

A substantial part of rainfall and runoff is lost through evaporation and transpiration. As much as 90 percent of applied water, or more in some areas of the West, are lost to evaporation and transpiration by plants. Vegetation management involves removal of natural vegetation to reduce water loss by evaporation and transpiration. Various techniques of vegetation management to reduce evapo-transpiration have been studied including: (1) removal of natural vegetation, (2) coating plant leaves with a film to reduce transpiration (3) substituting crops with low transpiration rates, and (4) genetically reducing transpiration rates.

Most phreatophytes are low value plants that cover about 16 million acres of land consuming from 20 to 25 million acre-feet of water per year. It is unknown to what extent phreatophyte control can contribute to increasing water supplies. One estimate is that the flow of the Colorado River could be increased as much as 4 million acre-feet per year if all forests and brush lands were managed solely to increase water supply. However, these are unrealistic goals when other forest resources, economic and environmental factors are considered. In considering the desires of a specific project, it was estimated that 42,000 acre-feet per year could be added by managing

250,000 acres of subalpine forests in the Upper Colorado River Basin or 210,000 acres of chaparral in the Lower Colorado River Basin.[6]

There are no detailed studies on the overall potential for vegetation management to augment the Nation's water supplies.

WEATHER MODIFICATION

Weather modification by cloud seeding is not a technique which can be used to end severe droughts, but it may increase precipitation by initiating or extending the duration of snow or rainfall. Cloud seeding involves dispersing crystals of carbon dioxide or silver iodide into certain cloud formations in an attempt to increase snow and rainfall. This technique is being studied in some of the Western States as a way to increase the snow pack in mountains above 8,000 feet. In general, the goal of cloud seeding is to keep the annual snowpack close to the long term average in years of below average snowfall.

The potential of winter cloud seeding for increasing the water supply in the 11 Western States has been investigated for 12 river basins - the Upper Colorado, Rio Grande, Truckee-Walker-Humboldt, Sacramento, San Joaquin, North Platte, Upper Missouri, Bear-Wasata, Gila, Snake, Deschutes, and Yakima Basins. It is estimated that average annual water supplies could be increased from 7.5 to 10 million acre-feet in these 12 basins. For the Upper Colorado River Basin the potential increase in annual water yield could be from 6 to 9 percent and for the Upper Rio Grande from 8 to 11 percent.[4] For these two water-short basins, weather modification could make a contribution to meeting future water demands.

Increasing snow and rainfall in some areas may have an adverse effect on other areas. Also, water users benefiting from any increased supply from weather modification may not bear the cost of the program and it may be difficult to determine the owners of any water actually produced. The developer of a new water supply has a right to use it, but must also prove that he did create the new water supply. Some State Laws treat augmented precipitation the same as natural sources and deny benefits to the developer of the additional water.

The Federal Government has supported weather modification programs for more than 30 years through the Water and Power Resources Services (WPRS), the National Oceanic Atmospheric Administration and the National Science Foundation. WPRS is currently studying cloud seeding in five sub basins in the Upper Colorado River basin. The purpose of this study is to quantify some of the effects on water supply and some of the ecological aspects.

Weather modification offers the potential of increasing future water supplies. However, at the present time the technique is not sufficiently developed so that it can be incorporated in a plan for increasing supplies. Questions remain regarding: (1) the actual amount of new water that can be added to the overall supply by this method, (2) the ecological effects on the area and the impacts on outside areas, and (3) the water rights implications of any increased supply from this source.

WATER RIGHTS

A water right is a right, granted by law, to take possession of a natural source of water supply and put it to a beneficial use. In the United States, there are two major doctrines for establishing water rights: (1) common law doctrine of riparian rights, and (2) prior appropriation. A riparian right is based on ownership of land contiguous to a natural surface or ground water supply. An appropriative right is based on appropriation and use of water belonging to the public, with earlier rights having preference over later ones. The riparian doctrine is based on location and the appropriation doctrine is based on time. The opposing natures of these doctrines have caused difficulties in interpreting water rights in areas where both have been applied. Water law in the Western areas of the Nation generally follows the appropriation doctrine.

All of the 17 Western States recognize the doctrine of prior appropriation to some extent. In essence, the doctrine states that a user who is first in time is the first in right, so that during shortages later appropriators must cease their use in reverse order of priority. No rights are acquired under this doctrine for non beneficial use of water, i.e., the appropriation doctrine does not recognize a water right that is not used for beneficial purposes. There is some belief that the appropriation doctrine may encourage wasteful use of water because a right that is not used can be lost to a subsequent appropriator. For example, some farmers may resist adoption of conservation measures that could result in losing part of their water rights.

A report by the U.S. Water Resources Council summarizes ground water law and water rights related to ground water.[7]

The common law governs the allocation of ground water to some degree in 37 States while the remaining 13 - all Western States - adhere almost exclusively to the doctrine of prior appropriation. The common law may take the form of reasonable use, absolute use, or correlative use. The absolute use doctrine empowers a landowner to withdraw unlimited amounts of water from the land without liability for any damages which may result to other landowners; i.e., depletion of neighboring wells through lowering of the water table. The reasonable use rule allows withdrawals of water in amounts necessary to the use or enjoyment of the land; generally, the only restrictions are that the water be applied to some beneficial purpose and that it not be transported away from the land overlying the point of withdrawal. The correlative rights theory bases the amount of withdrawals on the relationship between the volume of the aquifer and the size of the land overlying the aquifer.

Although in effect in the majority of States, the common law does not govern the allocation of ground water in all cases. When intensive management is required to prevent aquifer depletion (primarily in designated management areas), common law rights may not prevail. For example, the reasonable use doctrine in Arizona only applies in ground water basins outside of active management areas. The same holds true for States as diverse as Nebraska and Virginia. In Minnesota, where permits are required for withdrawals in excess of 10,000 gallons per day, a priority of use formula regulates ground water allocation when conflicts arise (domestic use is the highest priority).

The appropriation process may provide for a more efficient management capability during times of shortage because uses to precise amounts of water can be automatically curtailed according to a user's date of appropriation. Several Western States have modified this approach by authorizing a management agency to consider other management options. For example, in Montana, Nevada, and Oregon, the management agency may apportion the existing ground water supply among all users on an equal basis in a designated management area, or establish priorities of use (i.e., domestic, agriculture, industrial) during times of shortage.

ICEBERGS

A large percentage of the world's fresh water is trapped as ice in the polar regions and there has been considerable speculation concerning methods of using this source. The general concept is to tow icebergs to coastal areas of water short regions and melt them for fresh water supply. A proposed test project to tow icebergs to Australia is scheduled to start in the Fall of 1982.

Estimates are that fresh water from icebergs can be produced at 10 to 50 percent of the cost of desalted water. However, there are many unknowns and operation experience will be required to determine the technical feasibility and cost. The potential environmental and legal problems have also yet to be evaluated.

There are no detailed studies or estimates on the quantity of water that could be derived from this source for water supply augmentation in the Nation.

AGRICULTURAL IRRIGATION EFFICIENCY

Over 50 percent of all fresh water withdrawals in the Nation are for agricultural irrigation and this use is projected to continue through the year 2000. In some of the Western States over 80 percent of the fresh water supply is used for agricultural irrigation. Conservation and improved efficiency methods that have been proposed to reduce agricultural requirements include: (1) lining of conveyance and distribution systems, (2) more exact timing of water deliveries, (3) avoiding over deliveries, (4) water saving irrigation methods such as drip and trickle systems, and (5) improvements in irrigation scheduling (timing and application rates).

The term irrigation efficiency is applied to both off-farm conveyance systems and to on-farm conveyance and application systems. In the case of off-farm conveyance systems, efficiency is the volume of water delivered to the farm as a percentage of a total water diverted from a stream or other source. Loss of efficiency occurs from seepage through unlined canals or evaporation and other losses from lined canals and pipelines. On-farm efficiency is defined as the volume of water required for adequate crop growth as a percentage of the volume of water delivered to the farm. Overall irrigation efficiencies (combined off-farm and on-farm efficiencies) in the United States average about 41 percent.[6]

Methods to increase off-farm efficiency include lining of canals, installing pipelines, removal of vegetation in canals, and flow regulating and monitoring systems. On-farm improvements include lining of canals and installation of piping, irrigation system automation and more efficient application methods.

There are five phases in irrigation water use: (1) transpiration (2) runoff (3) evaporation (4) deep percolation and (5) moisture retention in the root zone. It is not possible to reduce transpiration without changing the crop. Runoff may be eliminated or more closely controlled by grading or using tail water return systems. There are three irrigation application methods in general use: surface flooding, sprinkler and trickle or drip systems. The efficiency of each method depends on the area characteristics and no single method is the most efficient in all cases. Some savings in evaporation may be possible by wetting smaller areas or changing to a different system such as drip irrigation. Deep percolation may be controlled by careful management, although water loss through deep percolation normally remains in the ground water supply. Moisture in the root zone may be more efficiently used by proper timing of water application.

Applications of water greater than the consumptive use requirement of the crop are necessary to leach salts through the plant root zone. Therefore, more irrigation water must be applied when water with higher total dissolved solids concentration is used. Many irrigation waters in the West exceed total dissolved solids concentrations of 500/1 and some exceed 1000 mg/1.

The amount of water that could be saved and used for other purposes through improvements in on-farm and off-farm efficiencies is uncertain. In a typical irrigation water system in the West, approximately 41 percent of the total water diverted is used by the crops being irrigated. This quantity of water can not be reduced unless the crop type or cropping pattern is changed. About 46 percent of the diverted water is returned to usable surface or ground water sources. Irrecoverable losses makeup the remaining 13 percent and include phreatophyte consumption, evaporation and losses to ground water that can not be retrieved. Irrecoverable losses vary by region and irrigation practices. In an eight State study area in the West, irrecoverable losses were estimated to be about 13 percent and it was concluded that it is difficult to make a significant reduction in these losses. However, in some areas irrecoverable losses may be as much as 20 percent and present opportunities for conservation.[6]

At a recent governor's drought conference in California, it was stated that irrigation is generally very efficient with a potential savings of only 0.7 million acre-feet available out of a total applied water requirement of 32 million acre-feet per year.[8]

The general conclusion is that, although agricultural irrigation is by far the largest water user in the Nation, it will be difficult to substantially reduce the quantity of water required for this purpose. The conservation methods that are available such as canal lining and changes in irrigation methods are relatively expensive and will be difficult to implement on a large scale basis.

CROP SWITCHING

It would be possible to conserve water by switching from high water using to lower water using crops. For example, alfalfa and other forage crops could be switched to vegetables or wheat. Alfalfa and pasture consume 3 to 6 acre-feet of water per acre per year in some areas of the West; in the same area, vegetables and wheat consume 1.6 to 2.2 acre-feet per acre per year. In many areas of the West the water intensive crops are grown to feed livestock production, e.g., alfalfa and hay are used as winter feed for cattle and pigs.

The major barrier to crop switching is that the economy of an area was developed based on particular crops and it is unlikely that sufficient markets exist, or that markets could be changed, to accommodate crop switching. Alternative crops may be used on a relatively small localized basis to reduce water requirements, but large scale crop switching will most probably not occur by the year 2000.

COOLING WATER TECHNIQUES

Cooling water for steam electric generating plants is the second largest water use in the Nation. Cooling is also the largest water requirement in many industries including primary metals, chemical and allied products, petroleum and coal products and food and kindred products. Dry cooling and wet-dry methods are water saving cooling techniques that are available to reduce water requirements. The cost of these alternatives will not be competitive with more conventional methods in some locations, but they may be feasible in some water short areas.

The substantial increase in water recycling projected to occur in the steam electric and manufacturing industries by the year 2000 is largely because of projected increases in cooling water conservation techniques.

MUNICIPAL CONSERVATION

Although the percentage of total water use for domestic and commercial purposes in most areas is small, opportunities for conservation do exist and should not be overlooked, particularly in water short areas. Professional societies have recently published detailed information on municipal water conservation methods.[9,10] Water conservation methods available and in use include flow reduction devices for faucets, shower heads and toilets, and timers for landscape irrigation systems.

Under an executive order by the Governor, the State of California has implemented water conservation programs as a condition of State and Federal grants for Clean Water Projects. Requirements apply to all systems with a wastewater flow greater than 70 gallons per capita per day, and systems serving more than 10,000 people are required to prepare a water conservation plan under Step 1 of the grant process. Projects that are awarded a grant will be required to implement a plan during the design and construction phases of the project. The water conservation plans are required to examine all measures used to conserve water in urban areas.

Several studies have shown that there is a relationship between the price of water and water use, i.e., as the price increases the demand decreases, particularly for outside uses. Water pricing may be used both as a constraint and a potential approach to water conservation.

SECTION 4

WATER SENSITIVE REGIONS

The purpose of this section is to evaluate the water supply situation in three different areas in the United States. Water supplies and demands and alternatives for the future are reviewed for the following three areas.

1. San Antonio, Texas. Ground water is presently the sole source of water supply for the urban sections in a five county area of South Central Texas that includes the City of San Antonio.

2. South Coastal California. About two-thirds of the water supplies for this 11,000 square mile area in Southern California are imported from the Colorado River and Northern California with the other one-third supplied from ground water and local runoff.

3. Yadkin-Pee Dee River Basin. Surface water and ground water from within this river basin are the sources of supply for an 18,000 square mile area in North Carolina and South Carolina.

SAN ANTONIO, TEXAS

The San Antonio study area considered in this evaluation is a five county area in South Central Texas that includes the City of San Antonio in Bexar County and Medina, Bandera, Kendall and Comal counties. This area shown in Figure 3 is the San Antonio River Basin, Zone 1, as defined by the Texas Water Development Board. The San Antonio area is also in Water Resources Council Region 12, Subregion 1205, as shown in Figure 4.

The population in the study area in 1974 was about 926,000 with about 900,000 of this total in the City of San Antonio which is the third largest city in Texas. The population is projected to increase to 1,382,000 by the year 2000 and 1,789,000 by 2020.

Mean annual precipitation in the area is about 26 inches and the average annual net lake surface evaporation is about 37 inches. Ground water is the principal source of water supply and the main source of ground water is the Edwards (Balcones Fault Zone) Aquifer. This aquifer is also referred to as the Edwards Underground Reservoir and is commonly known as the Edwards Aquifer.

The Edwards Aquifer is presently the sole source of water supply for the City of San Antonio and 16 smaller cities and towns in the San Antonio area, for five large military installations and for many farms and ranches in South

Figure 3. San Antonio River Basin - Zones 1 and 2

Reproduced from best available copy.

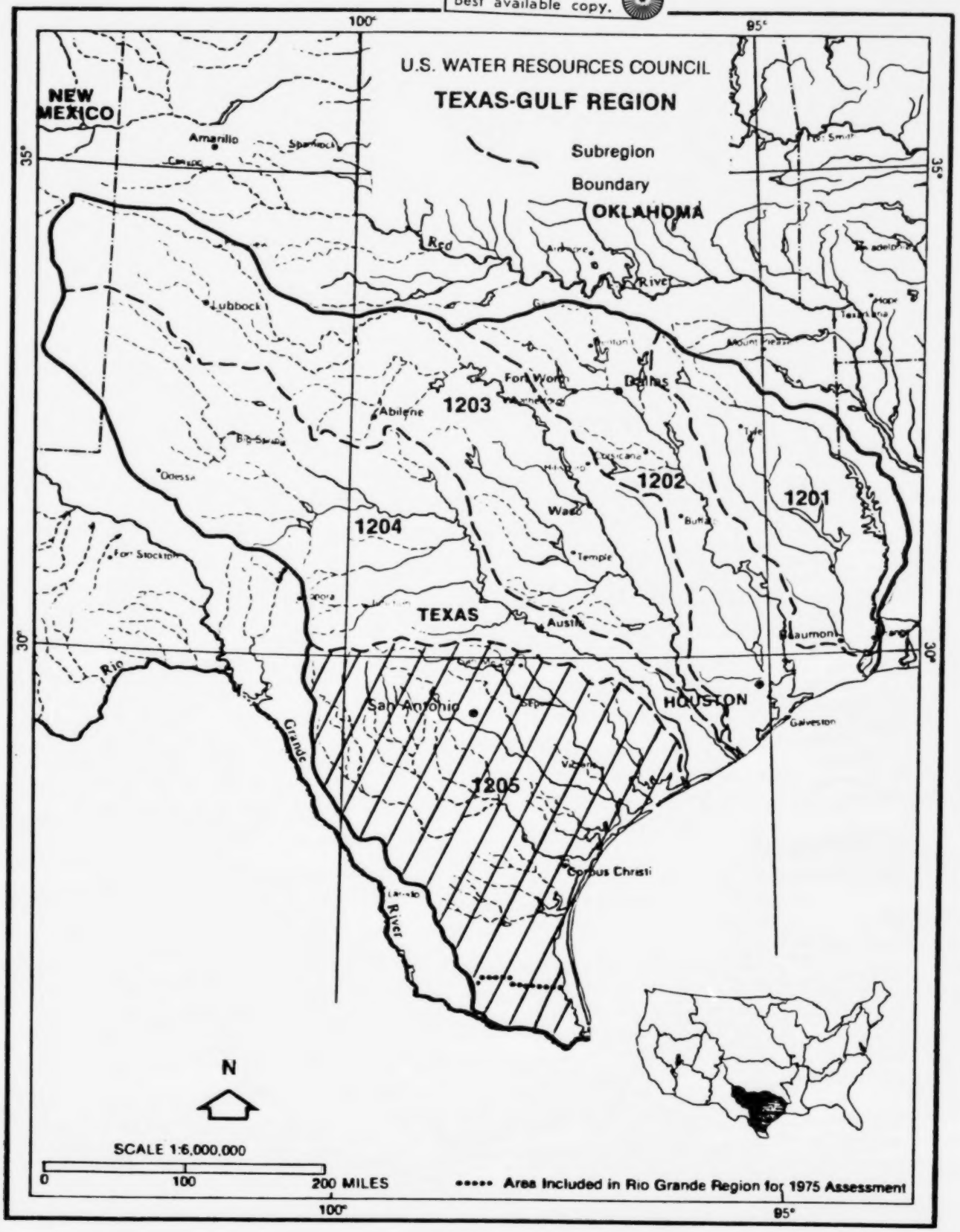

Figure 4. Texas-Gulf Region, Nueces-Texas Coastal Subregion 1205

Central Texas. The United States Environmental Protection Agency has determined that the Edwards Aquifer is a sole or principal drinking water source under Section 1424(e) of the Safe Drinking Water Act (Public Law 95-523).

Water Requirements

Annual water requirements and discharges for the Texas Gulf Region determined from data reported by the U.S. Water Resources Council[1] are summarized in Table 5. Annual water requirements projected by the State Water Development Board for the San Antonio area are summarized in Table 6. Almost all of the municipal water use in the basin is concentrated in the City of San Antonio and Bexar County. Also, almost the entire manufacturing water use occurs in Bexar County where the food and kindred products industry consume over 50 percent of water used in manufacturing. Both ground water and surface water are used in steam electric power plant cooling, and in 1975 there were 2,190 megawatts of installed steam electric power generating capacity in the San Antonio area. Irrigation has remained relatively constant since 1964 and water requirements are projected to remain at the level of about 40,000 acre feet per year through the year 2000, and beyond.

As shown in Table 6, total requirements in the San Antonio Basin are projected to increase from 229,000 acre-feet in 1974 to 476,200 acre-feet by the year 2000. Ground water use is projected to increase from 195,300 acre-feet in 1974 (180,300 acre-feet of which was pumped from the Edwards Aquifer) to about 310,800 acre-feet by the year 2000. Surface water requirements in Bexar County are projected to be about 84,000 acre-feet per year by the year 2000. Requirements for steam electric power plant cooling and irrigation are projected to be about 80,000 acre-feet per year by the year 2000 making the total surface water requirements in the study area about 164,000 acre-feet per year. It is also expected that, in addition, about 30,000 acre-feet per year will continue to be delivered to the adjacent Nueces River Basin for irrigation. Therefore, the total annual surface water requirements for the San Antonio area will increase to about 194,000 acre-feet by the year 2000.

Water Rights

The Prior Appropriation Doctrine and the Riparian Doctrine are the two basic doctrines of surface water rights recognized in Texas. A riparian right is obtained by virtue of ownership of land adjacent to a stream or water course, requiring no action other than the acquisition of title to the land. Appropriative rights are not related to the ownership of land. Originally the Prior Appropriation Doctrine was simply that any one needing water had the right to take it. Development and the associated increase in demand for water in Texas produced many limitations and modifications of the basic Appropriation Doctrine. Appropriative rights are now regulated by Texas law under rules and regulations of the Texas Water Rights Commission.

The following summary shows all of the authorized and claimed surface water rights in the San Antonio study area as of December 31, 1976.[11]

TABLE 5

ANNUAL WATER REQUIREMENTS AND DISCHARGES - DRY YEAR CONDITIONS
TEXAS GULF REGION, NUECES - TEXAS COASTAL SUBREGION

(all figures in thousand acre-feet except recycle rate)
(After U. S. Water Resources Council[1])

FUNCTIONAL USE	WITHDRAWALS				USES								DISCHARGES	
	Fresh		Saline		Recycle Rate		Gross		Consumption					
									Fresh		Saline			
	1975	2000	1975	2000	1975	2000	1975	2000	1975	2000	1975	2000	1975	2000
Agriculture	1,315	1,118	0	0	—	—	1,315	1,118	1,158	990	0	0	157	128
Irrigation	1,270	1,060	0	0	1.0	1.0	1,270	1,060	1,113	932	0	0	157	128
Livestock	45	57	0	0	1.0	1.0	45	57	45	57	0	0	0	0
Steam Electric	86	138	379	305	—	—	1,967	9,227	15	30	1	146	450	267
Manufacturing	132	230	479	0	—	—	2,367	6,501	66	181	0	0	545	49
Primary Mtls.	12	44	343	0	1.0	17.0	370	743	0	35	0	0	356	9
Chemicals	80	129	123	0	6.1	33.4	1,243	4,306	38	102	0	0	165	27
Food & Kindred	12	10	<1	0	4.3	9.1	53	92	6	7	0	0	7	3
Petroleum	26	39	10	0	19.1	33.3	684	1,309	20	31	0	0	16	8
All Other	2	8	2	0	3.8	6.5	17	50	2	6	6	0	2	2
Domestic	242	292	0	0	—	—	242	292	86	104	0	0	156	187
Central	233	283	0	0	1.0	1.0	233	283	81	99	0	0	153	184
Non-Central	9	9	0	0	1.0	1.0	9	9	6	6	0	0	3	3
Commercial	62	71	0	0	1.0	1.0	62	71	21	25	0	0	40	46
Minerals	220	224	0	0	—	—	1,428	1,419	146	148	0	0	74	76
Non-Metals	38	42	0	0	1.9	1.9	74	81	3	4	0	0	35	37
Fuels	177	174	0	0	7.6	7.6	1,348	1,322	141	142	0	0	36	31
Metals	4	9	0	0	1.9	1.9	7	17	1	1	0	0	3	8
Other	3	3	0	0	1.0	1.0	3	3	0	0	0	0	3	3
TOTAL	2,062	2,075	858	305	—	—	7,385	18,631	1,493	1,478	1	146	1,426	757

TABLE 6

ANNUAL WATER REQUIREMENTS
SAN ANTONIO RIVER BASIN - ZONE 1

(all figures in thousand acre-feet)
(After Texas Water Development Board[11])

FUNCTIONAL USE	Ground Water		Surface Water		Total	
	1974	2000	1974	2000	1974	2000
Agriculture						
Irrigation	23.5	21.2	15.1	16.5	38.6	37.7
Livestock	1.1	1.5	1.4	1.8	2.5	3.3
Steam Electric	2.3	4.1	16.9	63.3	19.2	67.4
Manufacturing	16.1	16.7	0.3	6.2	16.4	22.9
Municipal	149.3	262 8	-0-	77.6	149.3	340.4
Mining	3.0	4.5	-0-	-0-	3.0	4.5
TOTAL	195.3	310.8	33.7	165.4	229.0	476.2

FUNCTIONAL USE	SURFACE WATER RIGHTS (acre-feet)
Agricultural Irrigation	89,256
Steam Electric	75,000
Manufacturing	48,903
Municipal	1,472
Mining	- 0 -
Recreation	4,659
Recharge	961
TOTAL	220,251

The water rights for municipal purposes are small because the Texas Water Ajudication Act of 1967 authorizes the Texas Water Rights Commission to investigate and recommend water rights in surface water streams, except for domestic and livestock uses.

In contrast with the extensive and direct involvement of the State in controlling surface water supplies through its control over surface water rights, the State cannot control water use practices involving ground water. Texas courts have followed the rule that the land owner has the right to use or take for sale all water beneath his land. The courts have chosen not to adopt any rules based on reasonable use of ground water. Owners of land overlying defined ground water basins may adopt voluntary regulations through mutual association in underground water conservation districts and the Texas Water Code provides for the formation of these districts. The Edwards Underground Water District is one such district that serves the San Antonio area.

Water Supplies

The summary of annual water requirements in Table 6 shows that in 1974 about 85 percent of the water used in the San Antonio area was ground water. Essentially the only surface water use was for agricultural irrigation and steam electric power plant cooling. Most of the ground water used is pumped from the Edwards Aquifer; however, a relatively small quantity is pumped from the Carrizo-Wilcox Aquifer for irrigation in Southern Bexar County. The estimated safe annual withdrawal rates in the San Antonio area in the year 2000 are 285,100 acre-feet from the Edwards Aquifer and 14,300 acre-feet from the Carrizo-Wilcox Aquifer.

The Edwards Aquifer--

The Edwards Aquifer supplies municipal and industrial water to most of the cities and towns in the study area including the total municipal and industrial water supply for the City of San Antonio. Well capacities are high with some wells owned by the City of San Antonio producing over 16,000 gallons per minute.[12,13]

The Edwards Aquifer consists of the Edwards and associated limestones that range in thickness from about 400 to 700 feet and yield large quantities of water due to the extensive honeycomb nature of the limestone formations. The aquifer hydrologically connects the San Antonio River Basin with the

Guadalupe River Basin to the East and the Nueces River Basin in the West. It is the major source of Water supply in the upper parts of all three basins.

Water in the Edwards Aquifer is discharged naturally at San Antonio and San Pedro Springs in San Antonio and at several other springs near Uvalde, New Braunfels, and San Marcos. Some of the largest springs in the State are the result of natural discharge from the Edwards Aquifer including San Antonio Springs in San Antonio. The San Antonio River is formed from the flow of San Antonio Springs and several tributaries join the River downstream as it flows to the Gulf of Mexico. Before there were any withdrawals from wells, essentially all the recharge that entered the Edwards Aquifer was discharged through six major springs. The spring flows have decreased proportionate to the pumping of water from the aquifer.

Natural recharge of the aquifer occurs primarly by infiltration of surface water from streams which traverse outcroppings. Some recharge also occurs by direct infiltration of precipation on the outcrop and about 5 to 6 percent of the recharge is from underflow from another formation. Average annual recharge from the 1934 - 1974 period was approximately 563,000 acre-feet which can be considered as the dependable annual yield without mining the aquifer. However, averages computed over this 40 year period do not reflect the droughts which can and do occur. Overdrafts in the Edwards Aquifer have occurred during droughts such as the 1950 - 1957 period. A detailed study and model analysis of the Edwards Aquifer by the State in 1979 indicates that 425,000 acre-feet can be safely withdrawn annually from the aquifer to serve the Guadalupe, San Antonio, and Nueces River Basins. It is estimated that 285,100 acre-feet per year is the amount that can safely be withdrawn in the San Antonio Basin. The remainder of the 425,000 acre-feet per year is required for supply in the Guadalupe and Nueces River Basins.[14]

Artificial recharge of the aquifer has been conducted for several years with good success. Dams have been constructed across intermittant streams in the outcrop area to retard flood waters and allow infiltration. The existing structures provide the capability of recharging approxiately 40,000 acre-feet per year. Additional structures planned by the Edwards Underground Water District, the Corp of Engineers and the U.S. Soil Conservation Service could provide additional recharge capabilities of about 80,000 acre-feet per year.

The total pumping from the Edwards Aquifer for all uses is estimated to be 636,000 acre-feet by the year 2000, and 906,000 acre-feet by 2020. The potential problem is the possibility that poor quality water at the Southern limits of the Edwards Aquifer might be drawn in to the fresh water section if water levels are lowered significantly. Because of the potential water quality degradation from over pumping and because the aquifer interconnects the San Antonio, Guadalupe and Nueces River Basins, there is a need for a coordinated management plan. The Texas Water Development Board initiated a comprehensive study of the three basins in 1971.[11] Basically, the results of the study indicate the need to institute an area wide management program. A conjuntive use management program coordinating ground water and surface water supplies could provide a minimum sustained flow in springs and also preclude the possibility of drawing poor quality water into the Edwards Aquifer along its Southern boundry. The proposed conjunctive use program would limit pumping

from the Edwards Aquifer to about 285,000 acre-feet per year within the San Antonio Basin, and about 272,000 acre-feet per year in Bexar County.

The Edwards Underground Water District and the Regional River Authorities have the primary responsibity for water resources development in the study area. The Edwards Underground Water District has been instrumental in coordinating an extensive and continuing water quality monitoring program in the aquifer and its recharge zone. The principal agencies involved in this program are the Edwards Underground Water District, the Texas Water Development Board, the Texas Water Quality Board, the U.S. Geological Survey, the City of San Antonio and the Bureau of Economic Geology at the University of Texas. The Texas Water Quality Board which has jurisdiction over water quality control in the State has taken two important actions to protect the Edwards Aquifer: (1) water quality standards for the streams crossing the recharge zone have been upgraded, and (2) criteria have been established for new developments proposed in the recharge area.

The Edwards aquifer is subject to contamination in the recharge area and it was on this basis that it was declared a sole source aquifer by EPA on December 16, 1975. In making the sole source aquifer determination under the provisions of the Safe Drinking Water Act, it was noted that contamination of a ground water aquifer can be difficult or impossible to reverse and that contamination of the Edwards Aquifer would pose a significant hazard to persons depending on this source for drinking water. As a result of EPA's determination that the Edwards Aquifer is a sole source aquifer, no commitment for Federal financial assistance through a grant, contract, loan guarantee or otherwise, may be entered into for any project which the EPA Regional Administrator determines may contaminate the aquifer through its recharge zone. Federally assisted projects that could impact the recharge zone such as housing developments, highways and sewage collection treatment and disposal facilities could be affected by this regulation.

Although EPA has determined the Edwards Aquifer to be a sole source aquifer, the ongoing local and State programs are very important in providing protection from projects that are not financially assisted by the Federal Government.

Surface Water--

Historically, the total flow of the San Antonio River has averaged about 500,000 acre-feet per year. Wastewater discharges from municipalities, primarily the City of San Antonio, and manufacturing industries were about 132,000 acre-feet in 1974, which constitutes a significant portion of the total stream flow. Estimated return flows from irrigation are relatively small being only about 4000 acre-feet in 1974.

Major reservoirs in the San Antonio Basin include Medina Lake, Olmos Reservoir, Victor, Braunig Lake, Calaveras Creek Reservoir, and Mitchell Lake. Medina Lake, located on the Medina River in Bandera and Medina Counties, is owned and operated by the Bexar-Medina-Atascosa Counties Water Improvement District Number 1 and provides water for irrigation in the San Antonio and adjoining Nueces River Basins.

Olmos Reservoir, located on Olmos Creek in Bexar County, is owned and operated by the city of San Antonio. This project is used as a floodwater-retention reservoir. Impounded floodwaters are stored only until releases can be made without damaging property in downstream areas. During periods when the reservoir is empty, the reservoir basin provides park and playground facilities.

Victor Braunig Lake and Calaveras Creek Reservoir are located in Bexar County on Arroyo Seco and Calaveras Creek, respectively. These projects are owned by the city of San Antonio and operated by the City Public Service Board to supply cooling water for steam-electric power generation. Water for cooling is also pumped from the San Antonio River when local runoff is insufficient.

Mitchell Lake is an 850-acre reservoir located south of the city of San Antonio in Bexar County and, until 1930, served as the only wastewater treatment facility for San Antonio. A Texas Water Quality Board permit authorizes the discharge of domestic sewage effluent and other wastewaters into the lake, and further authorizes discharges from the lake under certain emergency conditions, based on the volume of water in the lake and rainfall conditions in the watershed. Mitchell Lake for many years has served a significant role in the irrigation of land (as much as 4,000 acres) below and adjacent to it.

Water Quality

Water quality in the Edwards Aquifer is generally good with total dissolved solids concentration of less than 500 mg/l. Dissolved solids concentration in the upper part of the San Antonio River Basin are generally in the 300 to 350 mg/l range and concentrations in the San Antonio River below San Antonio usually exceed 600 mg/l.[15,16] The lower part of the Medina River and the upper part of the San Antonio River are affected by wastewater discharges from municipal and irrigation return flows.

Alternative Water Supplies for the Future

The estimated annual safe yield of aquifers in the San Antonio area is 299,400 acre-feet. The safe yield of the Edwards Aquifer is 285,100 acre-feet and the Carrizo-Wilcox Aquifer is 14,300 acre-feet. Therefore, on an average annual basis, there is adequate ground water to supply the projected demands. However, problems will arise when the inevitable dry periods occur and natural recharge of the aquifers falls below average levels. A supplemental surface water supply for the area served by the Edwards Aquifer is needed to insure an adequate water supply for agricultural, municipal and other uses. The region's population and economy are currently much larger than in previous periods of water shortages.

At the present time the only firm source of surface water supply available to the San Antonio area is Medina Lake which will provide an average of 39,000 acre-feet per year for irrigation use. About 30,000 acre-feet of this total will be delivered to the adjoining Nueces River Basin leaving only about 9,000 acre-feet per year for use within the San Antonio Basin. The remaining surface water requirements for irrigation may be met by reusing wastewater originating in Bexar County.

Requirements for steam electric power plant cooling are projected to increase from about 17,000 acre-feet per year in 1974 to over 63,000 acre-feet per year by the year 2000. It is possible that these requirements can continue to be satisfied with wastewater discharges from the City of San Antonio.

The projected municipal and industrial surface water requirements in Bexar County of about 84,000 acre-feet by the year 2000, will require the development of additional sources. The State and San Antonio City Water Board have studied several alternative reservoir and water transfer projects to provide supplemental supplies. Studies by the Texas Water Development Board indicate that the following developments could provide supplies to meet the requirements in the year 2000.

1. Staged construction of a conveyance facility from the Guadalupe River Basin to water treatment facilities in northeast San Antonio for the initial conveyance of 30,000 acre-feet annually from Canyon Lake, followed by construction of the authorized Cloptin Crossing Reservoir project in the Guadalupe River Basin and facilities for conveyance of an additional 20,000 acre-feet annually to Canyon Lake and then to Bexar County.

2. Staged construction of the Applewhite Reservoir project on the Medina River in Bexar County, which will provide a firm supply of 14,900 acre-feet annually, followed by construction of the authorized Cibolo Reservoir project on Cibolo Creek in Wilson County with facilities for the initial conveyance of 18,900 acre-feet annually from Cibolo Reservoir to Applewhite Reservoir via pipeline and then to the potential Applewhite water treatment plant for use in Bexar County.

It is estimated that even during drought periods these actions would provide a dependable supply of 54,000 acre-feet per year from within the Basin and an imported supply of about 69,000 acre-feet. These supplies plus reusing about 71,000 acre-feet of wastewater discharges for steam electric power plant cooling and irrigation could provide the total estimated surface water requirement.

In addition to these reservoir and transmission projects there are several other possiblities for meeting the future water requirements. A model of the Carrizo-Wilcox Aquifer indicates that approximately 40,000 acre-feet could be pumped from the artesian zone of the aquifer in Wilson County in the area southeast of San Antonio. However, declines in water levels would occur under this development plan, and these supplies could affect the availability of water for local users. This alternative would need additional study before it could be considered as a source of supply for Bexar County.

In 1973, the U.S. Army Corp of Engineers and the U.S. Bureau of Reclamation reported on the feasibility of supplying areas of West Texas and Eastern New Mexico with water imported from the Lower Mississippi River Basin. It is possible that such a project could also supply water to the other parts of Texas such as the San Antonio Basin. Cost estimates in projected 1985 prices were 53.5 billion dollars for the proposed West Texas project. Because

of the high costs, other alternative out of state sources of imported water are being investigated to reduce pumping and other costs.

Other methods of increasing the useable water supplies in the San Antonio Basin include conservation and augmentation through desalting, increased wastewater reuse, weather modification and conjunctive use of surface and ground water supplies. There are no large quantities of saline or brackish water in the San Antonio area, and desalting appears to offer limited potential for augmenting future supplies. However, wastewater reuse is and will continue to be an important source of water in the San Antonio area. Also, more intensive use of conjunctive use management techniques is proposed to more effectively use both surface and ground water supplies.

Weather modification has been studied rather extensively in Texas by the State and Federal Governments. The Texas Water Development Board has conducted research and development in weather modification technology. In 1974 the State entered into an agreement with the Department of the Interior to conduct a research program designed to develop technology and an operational management plan capable of producing additional rain from cumulus clouds in the high plains states East of the Continental Divide. However, no studies have been conducted specifically for the San Antonio area.

It is also possible to reduce future water requirements through conservation measures. It is estimated by the State that conservation measures among residential users alone could produce a 6 percent reduction in water use in the San Antonio area by the year 2000.[11] It may also be possible to reduce industrial and agricultural water uses through conservation. No detailed studies have been conducted on the impact that water conservation measures could achieve on future water requirements in the San Antonio Basin.

SOUTH COASTAL CALIFORNIA

The South Coastal California Area shown in Figure 5 extends about 200 miles from Ventura County southward to the Mexican border and about 50 miles from the Pacific Ocean eastward to the crest of the Coastal Range. The surface area is about 11,000 square miles. It includes all of Orange County and portions of Ventura, Los Angeles, San Bernardino, Riverside, and San Diego Counties. This area is included as a part of Water Resources Council Region 18, Subregion 1806, which is shown in Figure 6.

The South Coastal Area contains more than 53 percent of the population of the State. No other urban area in the United States is so far removed from its major sources of water. The area's highly productive economy has developed in a region with an average rainfall of less than 15 inches per year and no major rivers within 100 miles. Consequently, two-thirds of its annual water supply is imported through three aqueducts that extend between 200 and 500 miles from the basin:

- The Los Angeles Aqueduct, completed in 1913, brought water 340 miles to the City of Los Angeles from the Owens Valley on the eastern slope of the Sierra Nevada range. Extended 100 miles to the Mono Basin in 1940, the system now delivers 470,000 acre-feet per year.

FIGURE 5 - SOUTH COASTAL CALIFORNIA

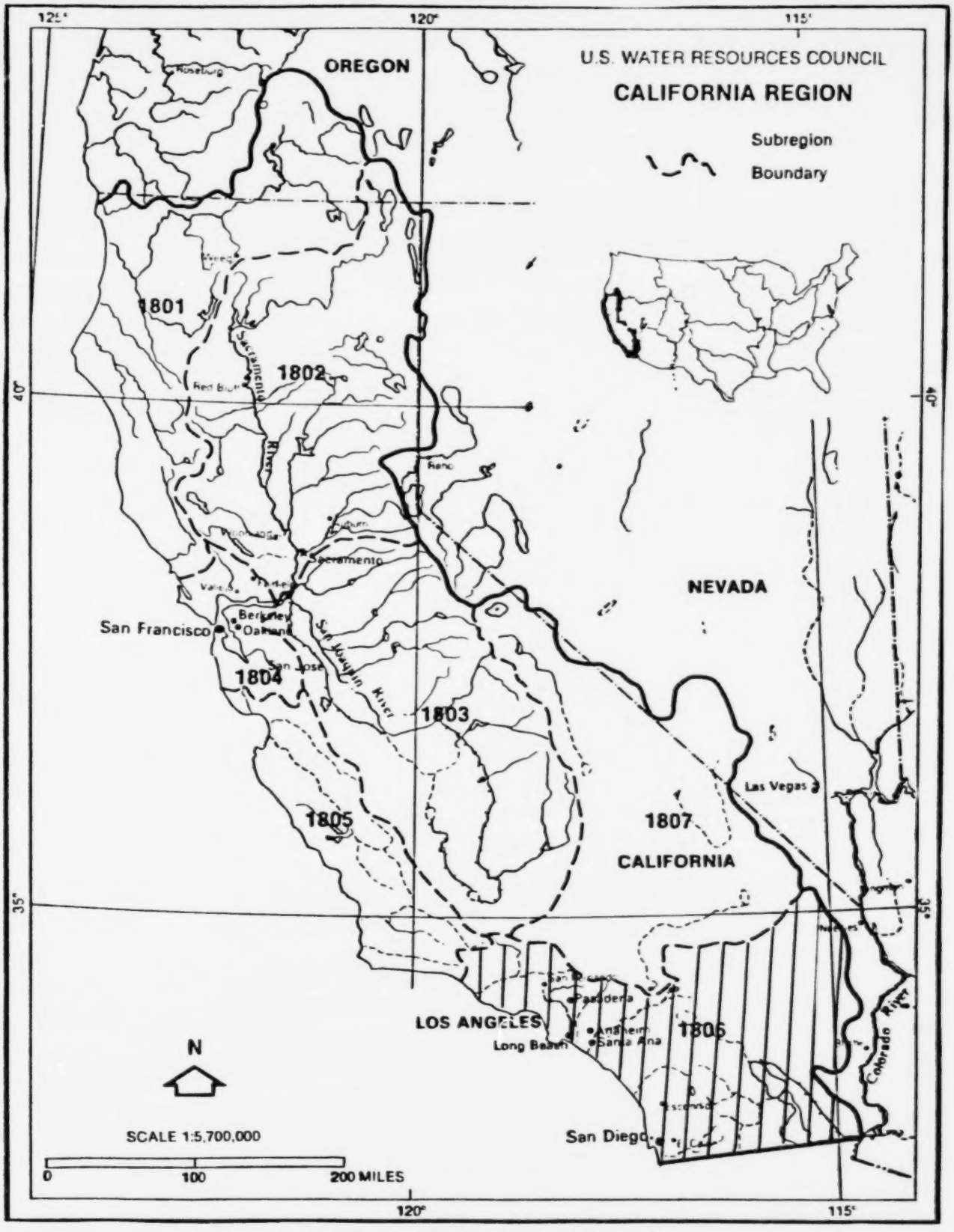

FIGURE 6 - CALIFORNIA REGION (WRC REGION 18)

- The Colorado River Aqueduct was completed by the Metropolitan Water District of Southern California (MWD) in 1941 to deliver water from the Colorado River to its service area covering the urbanized portions of six counties. The system has historically delivered an average of over 1,200,000 acre-feet per year. However, as the result of a long legal battle with Arizona, the MWD entitlement will be reduced to 550,000 acre-feet per year, or less, when the Central Arizona Project is completed in about 1985.

- The California Aqueduct is part of the State Water Project (SWP), and began delivering water to Southern California in 1975. Although the MWD entitlement is 2,011,500 acre-feet per year, only about 600,000 acre-feet per year are now being purchased. Curtailments in Colorado River water deliveries are expected to be offset by increases in SWP deliveries.

The Four South Coastal Planning Areas

The South Coastal Area is divided into four planning areas by the California Department of Water Resources: Santa Clara, Los Angeles, Santa Ana, and San Diego (See Figure 5).[17]

Santa Clara--

The Santa Clara Planning Area includes the watersheds of the Ventura River, the Santa Clara River, and the Calleguas-Conejo stream system. The primary economic activity and the primary water user (about two-thirds of the total) is agriculture. However, a moderate amount of urban and industrial development has taken place in this planning area; the industrial activity, which is peripheral to the urban-industrial development in the Los Angeles Planning Area, is expanding.

Local water sources supplied 85 percent of the area's 1975 demands, and imported sources provided the other 15 percent. Imported water is provided by two agencies: the Ventura County Flood Control District, a SWP contractor that distributes water to local agencies and cities, and the Calleguas Municipal Water District, a member of MWD that also delivers water through local agencies and cities.

Los Angeles--

The Los Angeles Planning Area comprises the watersheds of the Los Angeles River, Rio Hondo, and San Gabriel River. The area, which consists primarily of the coastal portion of Los Angeles County, contains more than 32 percent of the population of the State. Only about 2 percent of total water use is for agriculture in this planning area. Urban-industrial development continues to encroach upon agricultural lands.

About one-third of the area's water supply is derived from local sources and the rest is imported. Imported water is supplied by three agencies: the San Gabriel Valley Municipal Water District, a SWP contractor that distributes water to local agencies and cities; MWD, which distributes water through several member agencies and cities; and the City of Los Angeles, which, as a

member agency of MWD, can receive SWP or Colorado River water but also imports water from the Owens-Mono area via the Los Angeles Aqueduct.

Santa Ana--

The Santa Ana Planning Area includes the Santa Ana River drainage basin and some adjoining coastal streams, the San Jacinto River drainage area, and interior drainage terminating in Lake Elsinore. The area contains portions of Riverside, San Bernardino, and Orange Counties. Agriculture accounts for about 40 percent of the area's total water use. The agricultural economy is expected to decline somewhat as urban-industrial use expands in the future.

About two-thirds of the Santa Ana Planning Area's water demands are supplied by local sources and the rest of the supply is imported. Imported water is provided by MWD and three local SWP contracting agencies and is distributed through local agencies and cities. The local contracting agencies are Crestline-Lake Arrowhead Water Agency, San Bernardino Valley Municipal Water District, and San Gorgonio Pass Water Agency.

San Diego--

The San Diego Planning Area encompasses the watersheds of the Santa Margarita River, San Dieguito River, San Diego River, Sweetwater River, and several other coastal streams. The area contains all coastal San Diego County and portions of Orange and Riverside Counties. Agriculture currently accounts for about 40 percent of the area's total water use. Agricultural development is expected to remain at about the present level, although urban-industrial development is expected to expand in the future.

About one-quarter of the area's current supply is derived from local surface and ground water sources and the rest is imported. Imported water is supplied to the many local water agencies by the San Diego County Water Authority, which is a member of MWD.

Existing and Projected Water Supply and Demand

Several State and local agencies make projections related to population growth and water demand for the Southern California area. The State Department of Water Resources (DWR) make population and water demand projections through their Southern District Office. The Metropolitan Water District of Southern California (MWD), the major wholesale water agency in the area, also makes population and water demand projections. The projections from the two agencies differ in some particular items, but are generally in agreement. Another comparison of future water demands and supplies was recently published by the Orange and Los Angeles Counties Water Reuse Study, based mostly upon information provided by MWD.

Department of Water Resources Projections--

The most recent water supply and demand projections for the South Coastal Area by DWR was published in August 1981.[17] Figure 7 shows the relationship between the 1975 water demand and supply and the projected water demand and supply in the year 2000.

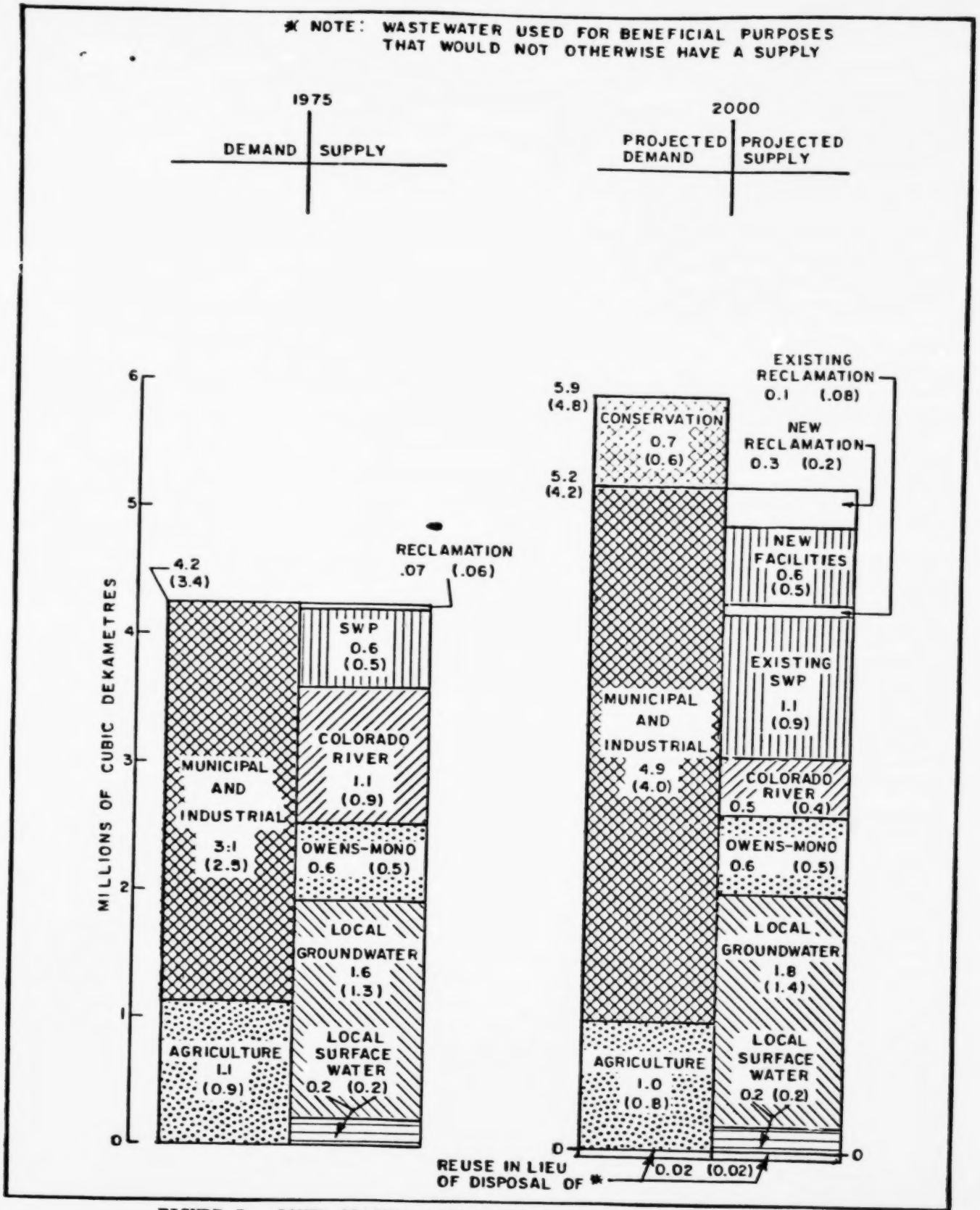

FIGURE 7 - SOUTH COASTAL AREA WATER DEMAND AND SUPPLIES
in cubic dekametres (acre-feet)

The projections indicate that if all the potential sources, including the existing and planned SWP facilities, are developed and if users are able to achieve the full conservation and reclamation goals, the study area's supply will be sufficient to meet the expected demand in year 2000. However, there is considerble controversy over some planned SWP facilities including the Peripheral Canal, and it is probable that the full conservation and reclamation goals will not be met.

Water Demand--The 1975 water demand was determined by DWR for each planning area by combining data on known deliveries by water purveyors with estimates of ground water extractions. Projected demands were derived in two parts. Municipal and industrial demand was estimated by applying projected per capita use values to population projections. Agricultural demand was projected by applying crop unit use values to projections of irrigated land. Table 7 contains water demands for 1975 and estimates for the year 2000 for the four planning areas, broken down into two categories: (1) municipal and industrial and (2) agricultural.

The following summary highlights the total South Coastal Area 1975 and projected year 2000 water demands.

- The study area's population was estimated to be 11,600,000 in 1975 and is projected to increase to 16,600,000 by the year 2000.
- Irrigated agricultural lands are expected to decrease somewhat from about 397,000 acres in 1975 to 317,000 acres by the year 2000.
- The anticipated demand achieved through municipal and industrial user conservation is projected to be about 15 percent below the demand projected on the basis of 1975 use patterns.
- The total demand for all uses, as projected on 1975 use patterns and then adjusted for projected anticipated conservation, will increase about 22 percent from 1975 to the year 2000.

Water Supplies--Major features in the water supply projections include the following.

- Surface waters in the South Coastal Area have been nearly completely developed by the various local agencies. The historical long-term average local surface water yield is 179,000 acre-feet per year. This amount is expected to be available through 2000.
- Local ground water provided 1,339,000 acre-feet in 1975 and is expected to supply 1,409,000 acre-feet in year 2000.
- The 1975 use of reclaimed water was 60,000 acre-feet per year. In the year 2000 it is expected that 315,000 acre-feet per year of reclaimed water will be used, an increase of over 400 percent.

TABLE 7
SOUTH COASTAL CALIFORNIA
APPLIED WATER DEMANDS BY PLANNING AREA

(all figures in acre-feet)
(After California Department of Water Resources[17])

Planning area	1975	2000[a/]
Santa Clara		
Municipal and industrial	117,000	281,000
Agricultural	244,000	196,000
	316,000	477,000
Los Angeles		
Municipal and industrial	1,451,000	1,872,000
Agricultural	24,000	b/
	1,475,000	1,872,000
Santa Ana		
Municipal and industrial	632,000	1,212,000
Agricultural	403,000	325,000
	1,035,000	1,537,000
San Diego		
Municipal and industrial	337,000	683,000
Agricultural	234,000	232,000
	571,000	915,000
South Coastal Area Totals		
Total municipal and industrial	2,537,000	4,048,000
Total agricultural	905,000	753,000[c/]
Total	3,442,000	4,801,000

a/ Municipal and industrial demand values for year 2000 in this table have not been reduced by the anticipated conservation amounts.

b/ Less than 1,000 acre-feet.

c/ The projected agricultural water demand reflects the encroachment into irrigated agricultural land by the year 2000 population projected from the preliminary 1980 census report.

- o DWR studies indicate that, with projected supplies and changes in use patterns to accomplish the anticipated conservation and reclamation, the total amount of imported water needed in 2000 would be 2,293,000 acre-feet per year.

- o Water imported to the study area in 1975 by The Metropolitan Water District of Southern California, the State, and the City of Los Angeles from various sources and the potentially available water from these sources in year 2000 are given in Table 8. The quantities shown as potentially available with existing facilities in year 2000 are based on rights, agreements, and delivery contracts of the individual agencies as of 1981.

Figure 7 indicates that additional facilities, including those of the SWP, would be required to provide on the order of 500,000 acre-feet per year by year 2000. If not all the local and SWP goals for water conservation and reclamation are met, additional facilities would be required to provide an even larger amount.

Metropolitan Water District Projections--

Several studies concerning present and future water supplies and demands have been made recently by the Metropolitan Water District of Southern California.[18,19,20] A summary of water supply and demand data for the MWD service area which appeared in the 1979 report is presented in Table 9. The supplemental water demand to be served by MWD and the total MWD supply available (based on dry year conditions) are presented in Table 10. These tables show deficits in the MWD supplies of 240,000 acre-feet per year in 1990 and 490,000 acre-feet per year in 2000. The population in the MWD service area is projected to increse from 11 million to 14 million people from 1980 to 2000. The major reason for the projected deficits is that MWD's Colorado River allotment will be greatly reduced in the mid-1980's when the Central Arizona Project begins operation. The projected deficits also assume that no additional facilities (including the Peripheral Canal) will be constructed for the State Water Project. Construction of the Peripheral Canal was rejected by the California voters in a statewide referendum in June 1982.

In March of 1982, MWD, in response to the statewide referendum in June 1982 published a report on the need for the Peripheral Canal.[19] This report contained the projections of future water demands and supplies for the year 1990, shown in Table 11. The 1990 comparison is based on a repeat of the 1976-77 drought conditions in California. This projection from MWD indicates a water shortage in the MWD service area of 750,000. acre-feet per year. The major difference between the 1982 MWD projections in Table 11 and the 1979 projections shown in Tables 9 and 10 is that the 1982 projections assume a much lower quantity of water being available from the State Water Project (600,000 acre-feet versus 1,030,000 acre-feet) during a critical dry period.

Orange and Los Angeles Counties Water Reuse Study Projections--

The Orange and Los Angeles Counties Water Reuse Study contains the projections of water supplies and demands for the MWD service area shown in Figure 8. The figure is discussed in the following excerpts from the reuse study:[21]

TABLE 8

SOUTH COASTAL CALIFORNIA IMPORTED WATER

(all figures in acre-feet)

(After California Department of Water Resources[17])

Importing Agency (Source)	Actual 1975	Potential 2000
City of Los Angeles Department of Water and Power (Owens-Mono)	452,000	467,000
The Metropolitan Water District of Southern California (Colorado River)	915,000	418,000*
Department of Water Resources (State Water Project)	496,000	890,000**
Total	1,863,000	1,775,000

*Potential amount is based on information obtained in 1981 from The Metropolitan Water District of Southern California and the Colorado River Board of California and could be reduced by the final court settlement of Indian claims.

**Based on 1981 SWP facilities, considering increasing water demands in the areas of origin, maturity of contractual obligations of the Federal Central Valley Project, and other prior rights.

TABLE 9

SUMMARY OF WATER SUPPLY AND DEMAND
MWD SERVICE AREA

(After Metropolitan Water District[18])

	thousand acre-feet		
Water Supply	1980	1990	2000
Los Angeles Aqueduct	470	470	470
Colorado River Aqueduct	1,150	450	400
State Water Project	1,060	1,030	990
Local Water Supply	1,100	1,170	1,250
TOTAL	3,780	3,120	3,110
Water Demand			
Urban	2,580	2,920	3,230
Agriculture	510	440	370
TOTAL	3,090	3,360	3,600
Supplemental Demand to be Served by MWD (See Table 10)	1,520	1,720	1,880
Surplus or (Deficit) in MWD Supplies (See Table 10)	690	(240)	(490)

TABLE 10

SUPPLEMENTAL WATER DEMAND TO BE
SERVED BY MWD AND TOTAL MWD SUPPLY

(After Metropolitan Water District[18])

	thousand acre-feet		
	1980	1990	2000
Total Water Demand MWD Service Area	3,090	3,360	3,600
Less Local Water Supply	1,100	1,170	1,250
Less Los Angeles Aqueduct	470	470	470
SUPPLEMENTAL DEMAND TO BE SERVED BY MWD	1,520	1,720	1,880
Water Supply Available to MWD			
Colorado River Aqueduct	1,150	450	400
State Water Project	1,060	1,030	990
TOTAL MWD SUPPLY	2,210	1,480	1,390
Surplus or (Deficit) in MWD Supplies	690	(240)	(490)

TABLE 11

FUTURE WATER DEMANDS AND SUPPLIES

(After Metropolitan Water District[19])

		acre-feet
1990 Demands on Metropolitan's System		
Overall service area demands		3,300,000
less probable local supplies		-1,200,000
less 1977 Los Angeles Aqueduct supply		-300,000
Net demands to be met by Metropolitan		1,800,000
1990 Supplies Available to Metropolitan		
Colorado River Aqueduct		
Metropolitan's 4th priority entitlement	550,000	
less conveyance losses	-60,000	
less prior Indian rights	-40,000	
Net Colorado River supply		450,000
State Water Project		
Actual State supply delivered in 1977	+200,000	
Plus supply exchanged with farmers	+400,000	
Net State project supply for Metropolitan		600,000
Total firm supply available to Metropolitan in 1990		1,050,000
Service Area Shortage in 1990 under 1977 Conditions		
Shortage in Metropolitan's supplies		750,000*

* 23% of service area demands

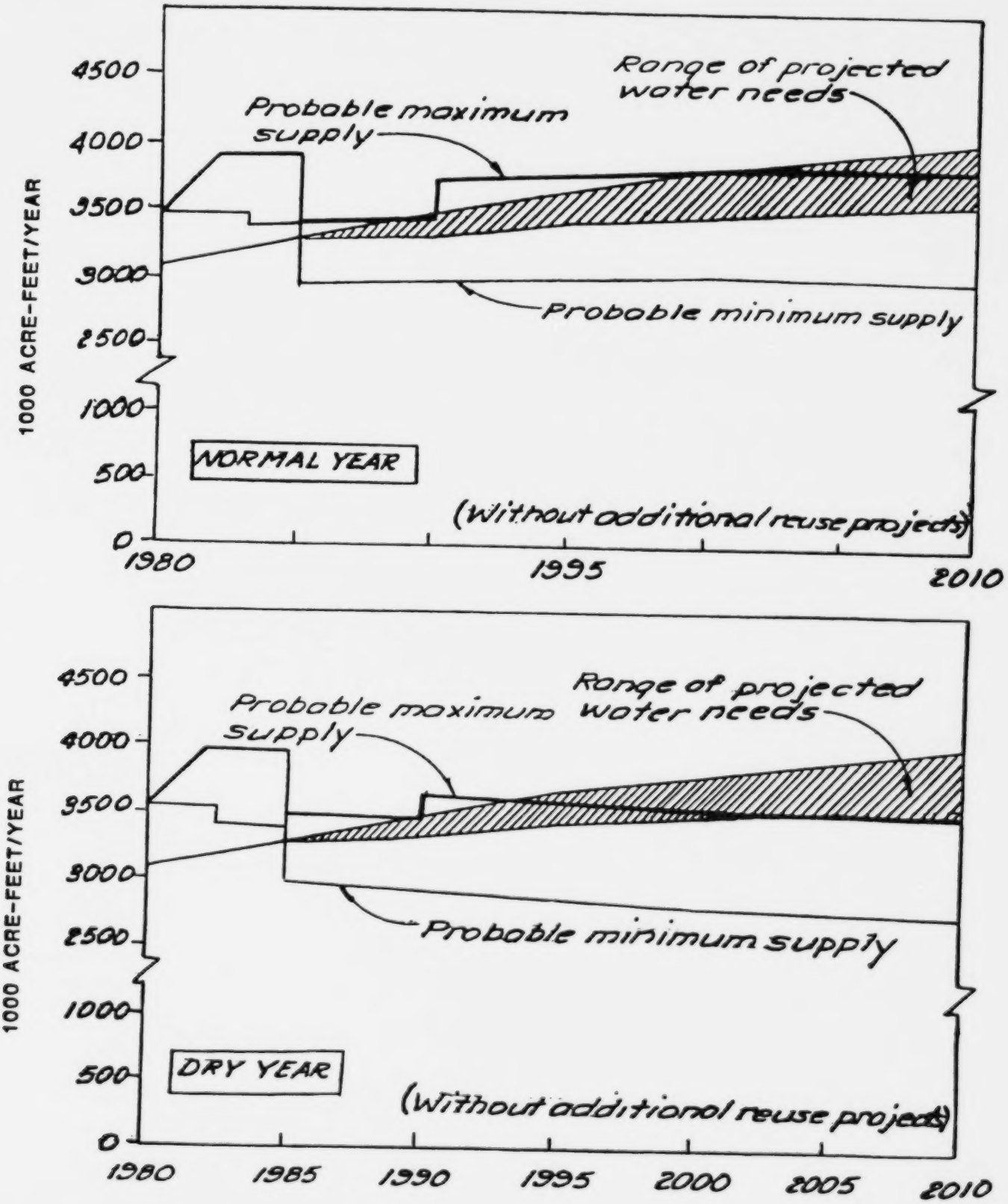

FIGURE 8 - FUTURE SUPPLIES AND NEEDS, MWD SERVICE AREA

". . . The fluctuations in the range reflect the possiblity of reduced supplies from the Mono Basin and the Colorado River, based on the possibility of judical decisions to award water rights to others and the projected diversions of Colorado River Water (CRW) into the Central Arizona Project schedule for 1985. The factors which might increase the supply include potential construction of the Peripheral Canal and other proposed units of the State Water Project (SWP). A 30 percent reduction in irrigation use has also been projected as well as a 4.5 percent decrease in per capita useage spread over a 30-year period. . .

. . . Note that by 1985, or shortly thereafter, there is a high probability that water needs will exceed available supplies. In any event, Southern California is entering a period of year-to-year uncertainty with regard to its water supply. In addition to the predictable changes, the water supply is subject to being modified by cyclical weather patterns, new legal challenges, or political and economic forces not even anticipated today. Periodic short-term shortages may become commonplace, and either voluntary or forced conservation will be employed to reconcile demand with supply. To reduce the negative social and economic impacts of these pending shortages, water agencies must seek to develop new freshwater supplies and make more efficient use of all existing supplies. Certainly it is time to stop wasting hundreds of thousands of AFY of highly treated wastewater to the ocean. Water reuse can be a dependable supplemental supply and should be integrated into the region's water supply program. Improved water conservation measures, storage of surplus wet-weather runoff in undergrround aquifers, and an expanded regional water reuse program are measures which will not eliminate the need for increased importation of freshwater. However, they will extend available freshwater supplies, reduce deficits, and demonstrate that the area will make maximum use of the new freshwater supplies which must be developed."

Water Resources Management Issues

Although each of the various Federal, State, and local water resources agencies involved acts independently within its own area of concern, there is a considerable amount of interdependence in their day-to-day operations and in their long range planning. However, one agency's solution to a resource management problem may not be acceptable to another agency or interest group. Several controversial issues in water resources management for the South Coastal Area which are not expected to be resolved in the near future are discussed in more detail.

Availability of Imported Water--

The estimates of potentially available imported water supplies for 1990 and 2000 are based on current rights, agreements, and delivery contracts of the individual agencies involved. Continued availability of these supplies in the amounts projected depends on certain controversial issues.

Owens-Mono Supply (City of Los Angeles)--The City of Los Angeles system is able to divert about 482,000 acre-feet per year from the Owens-Mono area and to deliver a long-term average of 467,000 acre-feet per year to the City. The difference between diversions and deliveries represents delivery system losses.

Management of this supply is being reevaluated, including all the identified categories of need, such as sustaining instream flow values in the area of origin and protecting Mono Lake. Two major issues will influence the future use of this supply: the lowering of water levels in Mono Lake and the proposed increase in ground water pumping in Owens Valley. Although a reduction in the importation from the Owens-Mono area could result from settlement of these issues, the amount and scheduling of that reduction is not predictable. The two major issues involved are:

1. Mono Lake. The Interagency Task Force on Mono Lake has recommended that diversions by the City of Los Angeles from the Mono Basin be reduced by 85,000 acre-feet per year below recent diversion amounts. Although the State concurs in the recommendations of the Task Force report, it also recognizes that the City of Los Angeles has a long-standing water right and a large-scale economic interest in the use of Mono Basin water and in hydroelectric energy generated by this water along the aqueducts. This issue is not expected to be resolved soon.

2. Owens Valley Ground Water Extractions. During dry years, the surface streamflow supplying the aqueducts is reduced and, to maintain the aqueduct flow, deep wells in the Owens Valley are pumped more heavily than in average or wet years. The City of Los Angeles proposes to increase its ground water extractions from Owens Valley to increase the system's total delivery capacity and reliability. The proposed increase is being protested by individuals and groups who anticipate adverse environmental impacts. Pending resolution of this dispute, a court order has been issued restricting the maximum pumping rate to 149.5 cubic feet per second. This reduces the quantity available for delivery by an amount ranging up to 119,000 acre-feet per year as influenced by surface hydrologic conditions.

Colorado River Supply--The MWD entitlement from the Colorado River is currently 1,212,000 acre-feet per year. In the mid 1980s, this will be reduced to 550,000 acre-feet per year as the Central Arizona Project begins its diversions from the Colorado River. The net dependable amount MWD can deliver from the Colorado River for beneficial uses within its service area will be about 418,000 acre-feet per year in the year 2000, after deducting: (1) 60,000 acre-feet for delivery system operating losses through seepage and evaporation, (2) 55,000 acre-feet per year for prior Indian water rights, and (3) 17,000 acre-feet for power plant cooling outside of the South Coastal Area.

The portion of that available supply which can be delivered to the South Coastal Area could be further reduced by possible additional Indian water rights claims. Changes in needs for desert power plant cooling water could also influence the available supply.

State Water Project Supply--Of the three systems importing water to the South Coastal Area, only the SWP has the potential to increase the amount being imported. However, while South Coastal entitlements to SWP water shown in Table 12 are more than adequate to cover the needed increase, the SWP must construct more facilities to develop additional dependable supplies before it can reliably furnish the full amount of water expected to be needed by its water contractors in year 2000.

The following excerpt from DWR's "Water Action Plan for the South Coastal Area" describes the projections of future SWP yields.[17]

> "In the future, SWP dependable deliverable yield is expected to decrease to between 1.6 and 1.8 million acre-feet per year, as a result of increased use in the areas of origin, maturity of contractual obligations of the Central Valley Project, and other prior rights.
>
> Assuming the dependable yield of the SWP is reduced to 1.7 million acre-feet per year by year 2000, the allocated share available to South Coastal Area SWP contractors would be about 0.9 million acre-feet. . . in the absence of any new facilities, the potential water shortages in the South Coastal Area will be 0.5 million acre-feet per year, even if all water conservation and reclamation goals for the area are met.
>
> With the proposed Peripheral Canal and other SWP future water supply projects currently being planned (ground water storage, Cottonwood Creek Project, Thomes-Newville Project, and Los Vaqueros Project), the SWP will have a dependable supply of water of excellent quality, sufficient to meet the expected needs under all existing contracts. With these facilities, the SWP will be able to deliver 1.4 million acre-feet of dependable supply to the South Coastal Area. At the same time, there will be better protection of the Delta-San Francisco Bay environment and local Delta water uses."

Conservation--

Department of Water Resources--The most recent water demand projections made by DWR shown in Figure 7 include a reduction due to conservation of 15 per cent by the year 2000 below the demand projected on the basis of 1975 use patterns.[23] It is anticipated that conservation will be accomplished through legal and institutional means, such as by mandatory use of water-saving toilets, showers, faucets, and appliances in new construction and by leak detection and repair.[23] This projected reduction includes the annual conservation of 40,000 acre-feet that took place from summer 1977 to July 1981 plus new, or additional, conservation of 656,000 acre-feet per year that is projected to take place by year 2000.

DWR has also estimated that there is an additional 10 percent potential reduction in demand that could be achieved through voluntary measures, such as habit change, use of low-water demand landscaping, retrofitting existing

TABLE 12

SOUTH COASTAL AREA
STATE WATER PROJECT CONTRACTORS
ANNUAL ENTITLEMENTS TO PROJECT WATER IN YEAR 2000

(After California Department of Water Resources[17])

Agency	acre-feet
Castaic Lake Water Agency	41,500
Crestline-Lake Arrowhead Water Agency	1,100
The Metropolitan Water District of Southern California	2,011,500
San Bernardino Valley Municipal Water District	102,600
San Gabriel Valley Municipal Water District	28,800
San Gorgonio Pass Water Agency	8,600
Ventura County Flood Control District	20,000
TOTAL	2,214,100

SOURCE: "Water Action Plan for the South Coastal Area," California Department of Water Resources, Southern District, August 1981.

toilets and showers, better industrial water use practices, and improvements in water purveyors' operations.

This combination of practices could provide a 25 percent savings by year 2000, without severely affecting users, as has been indicated in studies by DWR. However, DWR has concluded that in planning for future facilities and managing the South Coastal Area's long-term water supply, it would not be prudent to plan on continuous realization of the potential 25 percent user reduction in water use. A more realistic goal would be to accomplish a sustained 15 percent reduction from 1975 use patterns throughout the entire study area by year 2000.

Metropolitan Water District--The June 1979 MWD report does not contain any specific information on the water conservation included in the water demand projections.[18] However, the report did state that increased water conservation was included. An excerpt from the report compares DWR and MWD estimates and indicates that MWD assumed less water conservation than DWR: ". . . DWR assumes both higher overall water demands and higher water conservation, such that their net demands are close to Metropolitan's . . . ."

Orange and Los Angeles Counties Water Reuse Study--The projections of water supply and demand for the Orange and Los Angeles counties Water Reuse Study shown in Figure 8 included a 4.5 percent reduction in per capita water usage spread over a 30-year period.

The Effects of Water Conservation--Conservation may be considered as an additional source of supply. Therefore, the additional 10 percent potential component of conservation estimated by DWR might be relied on to extend the usefulness of developed supply systems in times of emergency. Portions of the South Coastal Area's water supply system are dependent on surface streamflow. During dry periods, less water will be available from those units of the supply system. The practice in the past has been to accommodate these periodic reductions in water sources by building a reserve storage capacity. Planned additional conservation by water users, during dry years, could reduce the amount of such reserve capacity needed.

Conservation programs will impact at least two other areas of water management: First, without adjustment in water rates, revenues would be temporarily reduced. Second, the amount of water available for reclamation would decrease and the concentration of organic and inorganic material in wastewater would increase. This second impact could reduce the potential for wastewater reclamation. Both of these factors are being considered by DWR and MWD in planning for water conservation.

Wastewater Reclamation--

Reclaimed wastewater cannot currently be used directly for potable purposes because of the uncertain public health effects. However, by using reclaimed water for irrigation of crops and landscaping, or for industrial cooling and process waters, existing supplies are released for domestic uses. Ground water recharge projects provide additional treatment and loss of

identity for reclaimed waters as they mix with existing ground water and other replenishment supplies. In this manner some reclaimed water is indirectly used for domestic purposes.

The Availability of Reclaimed Water--There are eight wastewater reclamation plants in Orange and Los Angeles Counties with a 1980 reclaimed water production of 121,500 acre-feet.[21] Construction of new facilities and expansion of existing flows is projected to increase available supplies by almost 100,000 acre-feet per year by 1985. In 1980, only 43,200 acre-feet were in use, with an additional 10,000 acre-feet committed in the near term. Based on these estimates, there will be almost 170,000 acre-feet per year of uncommitted reclaimed water available within the Study Area by 1985. This is over 100,000 acre-feet less than the potential market of 277,000 acre-feet shown in Figure 9. In addition, there are numerous treatment plants outside Orange and Los Angeles Counties but within the MWD service area which have reclaimed water available for reuse beyond their present commitments.

The Value of Reclaimed Water--The following excerpt from the Orange and Los Angeles Counties Water Reuse Study describes several ways by which the value of reclaimed water may be determined:[21]

> ". . . If there is a severe water shortage and reclaimed water reduces the potential economic impact and social costs of an insufficient supply, the value of the water may substantially exceed the economic cost of producing it. Even without a severe shortage, the replacement of existing uses of imported water with reclaimed water will reduce the power consumed in lifting northern water over the Tehachapi Mountains. Since the power savings are for the SWP's most expensive sources of power, the average, or melded, cost of SWP power is reduced for all SWP water deliveries to all SWP contractors and customers. So the primary beneficiaries of a reuse program in Southern California are the purchasers of SWP water and those in Metropolitan's service area whose water needs are met by the released water.
>
> The user of the reclaimed water may receive an economic benefit in the form of an incentive discount on his subpotable water rate but it may be some years before he knows whether there are any offsetting costs related to his dual system. His primary benefit may be in the form of a more reliable supply, particularly if his use is for irrigation or low priority industrial purposes. Such uses of imported water might be curtailed in time of shortage, whereas reclaimed water will still be available to protect his economic interests.
>
> If reclaimed water is judged in strictly economic terms, it is very likely that the sum of the amortized capital costs and the average annual operation and maintenance costs for most proposed projects will be greater than most potential customers now pay for water. The projects tend to be small so that unit capital costs are higher than for large water projects and the retail power rates that would be paid may be five times as high as the melded power rates

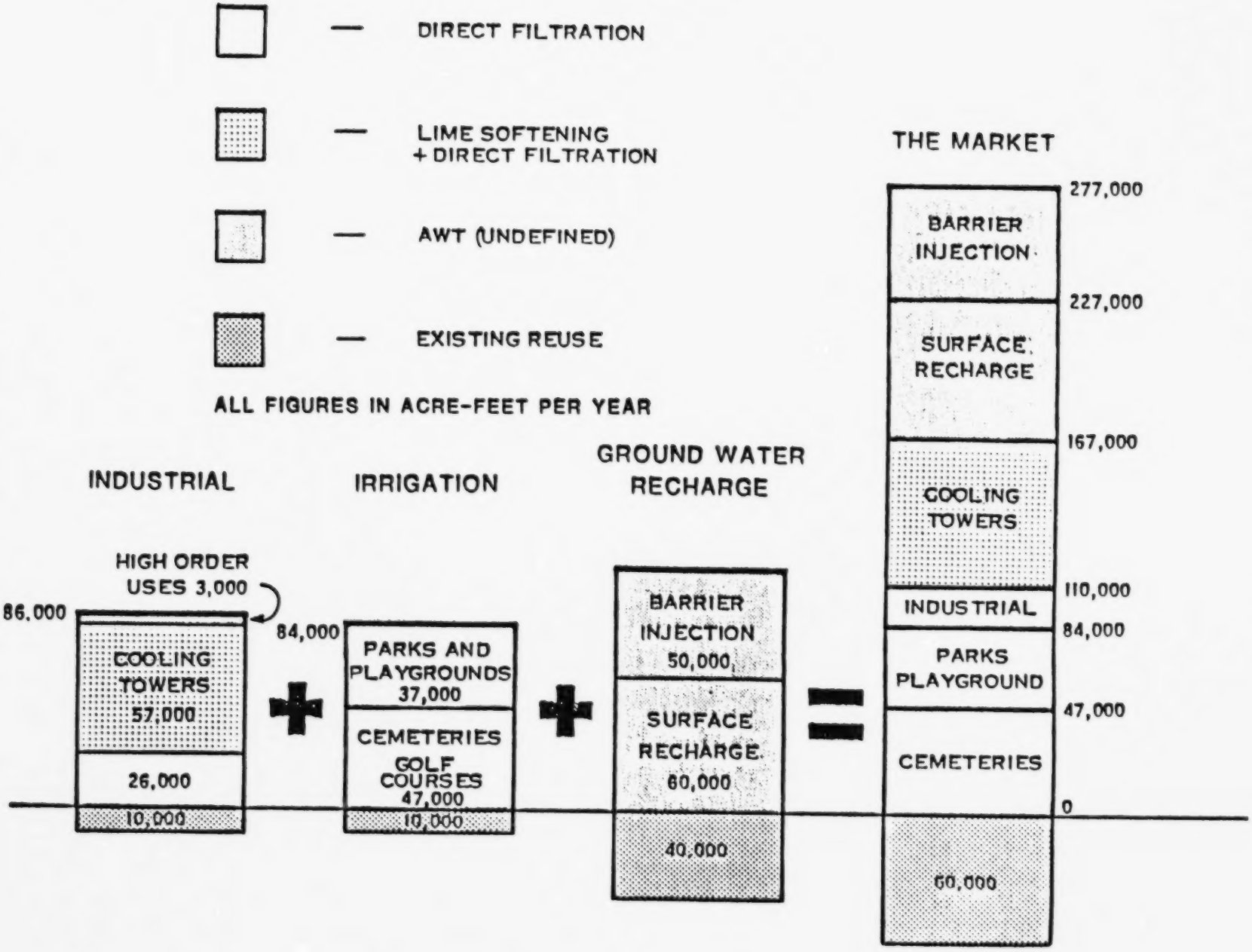

FIGURE 9 - WATER REUSE MARKET SURVEY

applied to SWP water, for example. Furthermore, water rates tend to be the average for all sources and the SWP and CRW systems were built when construction costs and interest rates were substantially lower than they are today. Therefore, if a user was expected to pay the full retail cost of a proposed reclaimed water project, he would find it may cost more than his present supply while most of the benefits would accrue to others.

The value of a water reuse program is therefore tied to the need for supplemental supplies in Southern California and the prospect that alternative fresh water supplies may not be developed in the near future. Even if they are developed, the unit costs of most of the proposed reuse projects identified in the study are less than the projected unit costs of all potential water development projects proposed for the SWP. . ., except the Peripheral Canal . . . Construction of the Peripheral Canal is still subject to the results of a State referendum, and even when it is built, it will not provide enough additional capacity to protect the region from potential water shortages in the near future."

A comparison of the projected costs of various possible methods of expanding the State Water Project with the average costs for 42 water reuse projects show that water reuse costs are less than all proposed SWP units except the Peripheral Canal. The existing Colorado River Aqueduct and existing SWP Oroville and San Luis Reservoirs do have substantially lower costs than wastewater reclamation projects because of lower construction costs and interest rates and because of lower power rates.

The average power cost to MWD to operate the Colorado River Aqueduct for the first 800,000 acre-feet per year is about $0.0025 per kwh. This rate will remain in effect until 1987 when existing Boulder Dam energy contracts expire. The energy requirement is about 2000 kwh per acre-foot of water; therefore the power cost is about $5 per acre-foot.

The average power cost for the SWP is about $0.003 per kwh in 1982, but will increase to about $0.02 per kwh April 1, 1983 when two low cost power contracts expire. The energy requirement is about 2900 kwh per acre-feet to bring SWP water to Southern California for a power cost of about $58 per acre-foot after April 1, 1983.

In contrast to these low power costs for imported Colorado River Water and State Project water, costs at a wastewater reclamation plant in Orange County were $0.068 per kwh in August 1982 on an interruptible service. This power cost is 27 times higher than the Colorado River Aqueduct, 23 times higher than the current SWP rate and 3.4 times higher than the April 1983 SWP rate.

Alternative Future Water Supplies

Potential sources of additional water supplies for Southern California include: (1) import from Northern California through facilities of the State Water Project, (2) ground water, (3) wastewater reuse, (4) desalination, and (5) Colorado River supply management.

Import from Northern California--

This is by far the most significant potential source of additional water for Southern California. Transfer of water from Northern to Southern California is a highly emotional and political issue and the ultimate outcome is uncertain. Many issues are unresolved and the quantity of water available to Southern California from this source will be uncertain for some time although it appears that new large scale water transfer facilities will not be constructed.

Ground Water Storage--

The Department of Water Resources' program for meeting future water needs includes storing water in groundwater basins in Southern California. The potential for storing water in ground water basins during wet periods and withdrawing it during dry periods has been recognized for many years. Interest was intensified in the early 1970's, with the increasing public opposition to the development of new onstream reservoirs as a means of augmenting water supplies.

In July 1978 DWR outlined its plans for developing a firm SWP yield from storage in Southern California ground water basins. These plans were incorporated into Senate Bill 200 (the controversial bill which includes the Peripheral Canal and other facilities). Studies of Chino, Bunker Hill, Yucaipa, San Timoteo, and Colton-Rialto ground water basins indicate that ground water storage could provide up to 400,000 acre-feet of SWP yield annually in the San Joaquin Valley and Southern California areas.

Wastewater Reuse--

The recently completed comprehensive study of wastewater reuse in Orange and Los Angeles Counties recommended a 34-project construction program that could produce an annual flow of 226,000 acre-feet at an estimated capital cost of $428.1 million at 1980 prices. The plan identifies 34 reuse projects at 20 locations. Construction would be divided into four phases, with 15 projects targeted for the first phase between 1982 and 1990. These would produce a combined flow of 34,000 acre-feet per year at a cost of $57 million. The study also proposes that the Metropolitan Water District of Southern California assist in financing the program and managing it as a subpotable category of water service in the same manner as other supplemental supplies. The preferred implementing approach is a series of joint ventures between MWD and local agencies, one joint venture for each project.

Of all the water reuses possible, including irrigation and industrial, the study concludes that the largest single market will be ground water applications such as replenishment of basins or seawater intrusion control along the coast. The study also predicts an ultimate market for reclaimed water of about 250,000 acre-feet a year over and above todays recycling of 50,000 acre-feet from existing plants which treat about 160,000 acre-feet each year.

One serious impediment to the development of wastewater reuse as an alternative to imported water is the cost of energy. Energy required for wastewater reclamation is comparable or somewhat less than energy required for pumping import water. However, the cost of energy for pumping import water is subsidized and is much less than the cost of energy for wastewater treatment

facilities. As a result, water costs are distorted and wastewater reuse appears economically infeasible in many cases when compared to importation.

Desalination--

DWR has identified six ground water basins in the Southern California area where brackish ground water could be extracted for desalting. The estimated annual yield from these basins is 39,000 acre-feet. In one of the six (Lower Chino Basin), the Santa Ana Watershed Authority is planning to desalt brackish ground water and has offered to sell it as an alternative to the SWP supply.

An existing wastewater reclamation facility for ground water replenishment in Orange County includes a reverse osmosis desalting system that is capable of producing 5,600 acre-feet per year. The highly treated effluent is injected into the Orange County basin to provide a barrier against seawater intrusion and for ground water replenishment.

Colorado River Projects--

Two plans have been put forth to better coordinate the management of the Colorado River and State of California supplies to Southern California and to conserve energy.

Colorado River Banking Plan--A cooperative study with DWR, MWD, and the Colorado River Board was initiated in 1979 and is to be completed by April 1982. The investigation will determine the merits of a banking program for long-term storage of MWD's share of Colorado River water in Lake Mead. Under this plan, MWD would reduce its Colorado River deliveries below its entitlement in years when the SWP has excess supplies available for delivery from Northern California. In return, MWD would receive storage credits in Lake Mead and would draw upon the lake during years of deficient SWP water supplies. The Colorado River Banking Plan could not be implemented until sometime after the Central Arizona Project becomes operational because adequate storage space is not expected to be available in the Colorado River reservoirs prior to that time.

Excess Colorado River Water--Calculations by DWR indicate that up to about 760,000 barrels of oil could be saved each year if MWD pumps an additional 400,000 acre-feet of Colorado River water annually instead of State Water Project water. That much less energy would be used to pump water from the Colorado River rather than from Northern California. The problem with this idea is that MWD's entitlement to Colorado River water is being reduced in 1985. Up until then, however, this plan would save SWP water and conserve energy.

YADKIN-PEE DEE RIVER BASINS
NORTH CAROLINA AND SOUTH CAROLINA

The Yadkin-Pee Dee Basin covers more than 18,000 square miles in North Carolina, South Carolina, and a very small area in Southern Virginia. The Yadkin begins as a turbulent stream at the foot of the Blue Ridge Mountains in North Carolina, and changes character to a broad slow moving river as it flows

to the Atlantic Ocean and enters Winyah Bay, an important harbor and estuary near the city of Georgetown, South Carolina. Major tributaries include the Lumber, Little Pee Dee, Lynches, Black, Waccamaw and Uwharrie Rivers. The Yadkin-Pee Dee River Basin is shown in Figure 10. The Basin is part of the Water Resources Council South Atlantic-Gulf Region, Subregions 301 and 302, as shown in Figure 11.

Population in the Basin is projected to increase substantially with a more than 30 percent increase over the next 30 years. The population was approximately 1,920,000 in 1980 and is expected to reach 2,150,000 by 1990 and 2,530,000 by 2010.[24] The most rapid growth is expected to occur in the coastal area and in the more urbanized northern third of the Basin. Employment in agriculture and the tobacco and textile industries is expected to decline. Manufacturing will remain the largest single employment category with electrical products, non electrical machinery, chemicals and instruments manufacturing industries expected to grow significantly in the next 30 years.

The projected land use in the Basin is shown in Table 13.

TABLE 13

PROJECTED LAND USE IN YADKIN-PEE DEE RIVER BASIN
(After U.S. Water Resouces Council[24])

	1990		2000		2010	
	Acres	Percent	Acres	Percent	Acres	Percent
Forest	7,389,500	59.3	7,308,500	58.7	7,144,600	57.3
Crops and Pasture	3,891,200	31.2	3,880,600	31.1	3,824,500	30.7
Urban	785,500	6.3	890,200	7.1	998,800	8.0
Other	392,200	3.1	380,000	3.0	490,400	3.9

These data indicate that forest is the largest land use category and will continue to be the largest through 2010. Agricultural land use is projected to decrease slightly and a substantial increase in urban land use is predicted. Urban areas are expected to grow at a rate which will require the conversion of about 213,000 acres to urban uses by 2010.

In the upper area, the W. Kerr Scott Reservoir is the first major impoundment on the Yadkee-Pee Dee main stem. There are six major impoundments in the rolling hills of the piedmont area at the base of the mountains: High Rock, Tucker Town, Badin Falls, Tillery and Blewett Falls. Total surface water area in the Basin is about 246,400 acres. Below these dams the Yadkin-Pee Dee reaches the "fall line" which is a series of low escarpments created by differing erosion rates of the piedmont and coastal plains soils,

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Figure 10. Yadkin-Pee Dee River Basin

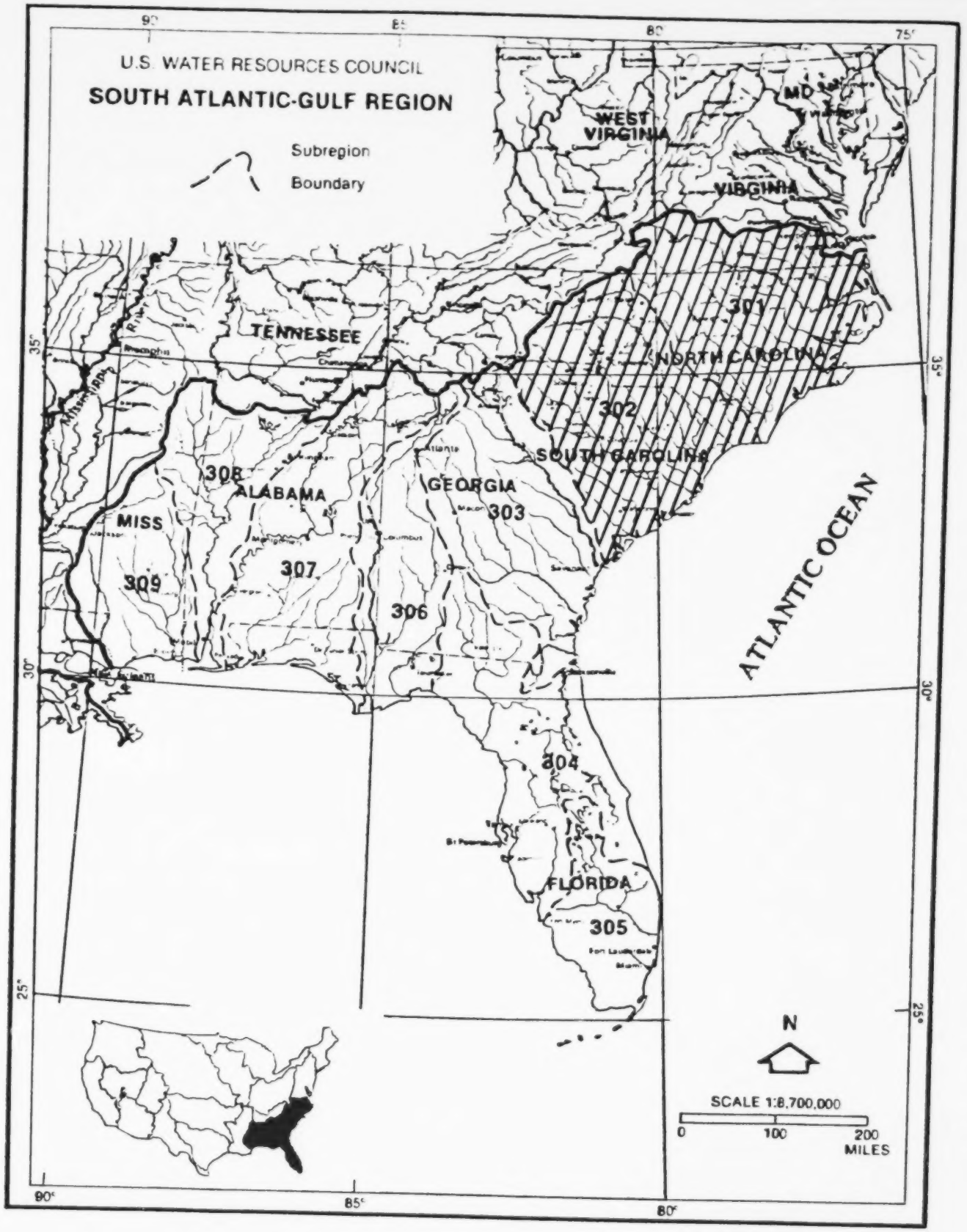

Figure 11. South Atlantic-Gulf Region, North Carolina and South Carolina, Subregions 301 and 302

and the underlying bedrock. The rivers of the coastal plain are broad meandering streams which terminate in large areas of wet lands throughout the coastal plains. Winyah Bay is the estuary for the Yadkin-Pee Dee River.

The average rainfall in the Basin is 44 to 56 inches per year. Droughts occur occasionally in North Carolina and about every seven to eight years in South Carolina. The average flow of the Yadkin-Pee Dee River at Wilkesboro, North Carolina is 520 million gallons per day (mgd). Further downstream near Mocksville the average flow is 1900 mgd, increasing to 5100 mgd at Rockingham and 8850 mgd where the river enters Winyah Bay.

Currently, major public water systems and self supplied industries withdraw about 300 mgd from surface streams and ground water. This use is projected to increase to about 612 mgd by 2010. The electric power industry currently has a consumptive water use of about 18 mgd, largely for evaporative cooling. Consumptive use for cooling is projected to increase to about 63 mgd by 2010. Water use for agricultural irrigation is currently about 40,000 acre feet per year and is projected to increase to about 120,000 acre-feet by 2010. Approximately 80 percent of irrigation water is withdrawn from streams and ponds with the remaining 20 percent from ground water.[25]

The significant increase in water demands estimated from the projected population growth in North Carolina and South Carolina prompted the two states to enter into a Level B Study with the U.S. Water Resources Council.[26] The study resulted in a plan consisting of 56 independent but interrelated recommendations. The 56 recommendations were divided into the following four categories for environmental analysis.[27]

- o Water supply
- o Water Quality
- o Flood Plain Management
- o Water Management

All of the 56 recommendations are grouped into these four categories in Table 14. The priority assigned to each of the recommendations by the Level B Study, high (H), medium (M) or low (L), is also shown in Table 14.

All 56 recommendations deal with programs, policies and studies; none recommend construction although many call for studies that may result in recommendations for construction. An analysis of the recommendations according to the type of action involved is shown in Table 15.

At the conclusion of the Level B Study, the greatest concern was the projected large increase in water demand resulting from increasing population.

Water Requirements

Current and projected water requirements for major public water systems, self supplied industries, electric power generation and agricultural irrigation are shown in Table 16. Water use by major public water systems and industries is expected to more than double by 2010 from the current use of about 300 mgd to 612 mgd. The electric power industry is the largest water user in the Basin. Nonconsumptive uses to generate electricity in hydro electric plants is projected to remain at the current level. Consumptive use

TABLE 14

RECOMMENDATIONS BY YADKIN-PEE DEE RIVER BASIN
LEVEL B STUDY

(After U.S. Water Resources Council[27])

Priorities		
NC	SC	
		Water Supply
H	M	Groundwater data collection: improve program
M	M	Groundwater data management: improve system
H	M	State water supply technical assistance: expand programs
L		Processing 404 permits (NC): improve procedures for water supply projects
M		Rocky River reservoir: start feasibility study
M		South Yadkin River reservoir: start feasibility study
L		Drowning Creek reservoir: start feasibility study
L		Ararat River reservoir: start feasibility study
M	M	Irrigation technical assistance: improve programs
M		Financing water supplies (NC): improve support program
	L	Financing water resources development (SC): develop support program
H	M	Water conservation: promote
H	H	Water supply source protection: coordinate existing programs
M	M	Water supply source protection: develop new programs
M		Potential Industrial and power plant sites (NC): encourage protection
		Water Quality
H	H	Water quality monitoring programs: change emphasis
H		High Rock Lake eutrophication: start study
M		Brunswick County shellfish: complete study
	M	Agricultural nonpoint source problems (SC): develop control strategies
H	H	Erosion control: enact and enforce law (SC); Improve enforcement (NC)
M	M	Urban stormwater runoff: apply results of demonstration studies
M		Water quality program funding (NC): increase state role
H	H	Agricultural nonpoint source controls: implement voluntary program
H		Agricultural nonpoint source control measures (NC): concentrate in high priority areas
L		Reclassification of Big Shoe Heel Creek and Bridge Creek: examine
M		Effluent standards on controlled streams (NC): modify
M	M	Groundwater: classify aquifers; enact standards (SC)
M	M	Biological water quality standards: enact
L	L	Sediment standards for streams: study feasibility
L	L	Special urban stream classification: determine feasibility
		Water Management
H		Water shortage emergency (NC): develop model ordinance and model plan
	M	Water shortage emergency (SC): develop plans and procedures
L		Processing 404 permits (NC): improve procedures for water supply projects
M		Financing water supplies (NC): improve support program
	L	Financing water resources development (SC): develop support program
H		Hydropower development: encourage
L		Public access to waterways (NC): improve
	L	Navigable waters and tidelands (SC): clarify public rights
M	H	Special designation areas: protect sites of potential value
	M	Little Pee Dee River special designation: start feasibility study
H	M	Protection for instream flows: establish policy; develop criteria
H		Water management system (NC): make incremental improvements
	H	Surface water management (SC): enact law
M		Interbasin transfer (NC): maintain existing law
L		Perkins Nuclear Power Plant: review position periodically
	H	Winyah Bay area economic development plan: start
		Floodplain Management
M	M	Wetlands values and development: conduct research
M	M	Soils mapping: concentrate on priority areas
H	H	Flood hazard studies: concentrate on priority areas
H	H	Floodplain management information: implement statewide programs
H	H	Floodplain management: take actions at local level
H	H	State floodplain management technical assistance: improve programs
M	M	Local flood control: continue five feasibility studies; start 29 feasibility studies
M	M	Agricultural flooding: increase efforts to reduce damages
M	M	National Flood Insurance Program: evaluate effectiveness in Basin
L	L	Effects of Level B floodplain management recommendations: evaluate in future
M	M	Wetlands definition for management purposes: develop guidelines
H	M	Unique and sensitive areas: accelerate protection
L	L	Federal Water Bank: extend program

NOTES:

NC - North Carolina
SC - South Carolina

Priorities:
H - High
M - Medium
L - Low

TABLE 15

ANALYSIS OF RECOMMENDATIONS BY TYPE OF ACTION
(After U.S. Water Resources Council[27])

Type of Recommendation	Number of Recommendations in Each Category[a]				
	Water Supply	Water Quality	Flood Water Reduction	Fish, Wildlife and Recreation	Water Management In General
Maintain status quo	1	0	0	0	1
Establish new policy; submit legislation	3	4	0	0	3
Revise or improve existing programs	4	4	4	2	5
Develop new programs	1	3	2	1	1
Evaluate existing programs	0	0	2	0	0
Continue ongoing site-specific studies	0	1	1[b]	0	0
Start site-specific studies	4	2	1[c]	1	1
Start basinwide or statewide studies	0	3	0	1	1
Improve procedures	0	0	0	0	3
	13	17	10 [b,c]	5	15

[a]Four recommendations are counted in two categories, all others in only one.
[b]Contains 5 ongoing studies in a single recommendation.
[c]Contains 29 proposed new studies in a single recommendation.

by steam electric generating plants, mostly for evaporative cooling, is currently about 18 mgd and is projected to increase to 63 mgd by 2010.[24]

Irrigated lands are projected to increase to about 118,000 acres by 2010 resulting in an increase in irrigation water use from the current 40,000 acre-feet per year to about 120,000 acre-feet per year. At the present time about 80 percent of irrigation water is supplied by streams and ponds with the remainder from ground water. Irrigation with ground water is expected to increase to about 35 percent in the coastal area of the Basin.

Water Rights and Water Management

Water laws and the approach to water management differ somewhat between the two States in the Yadkin-Pee Dee River Basin. North Carolina employs a designated area approach to the management of ground water. The Environmental Management Commission in the State Department of Natural Resources is authorized to designate capacity use areas where the use of ground water and surface

TABLE 16

ANNUAL WATER REQUIREMENTS
YADKIN-PEE DEE RIVER BASIN
(After U.S. Water Resources Council[24])

Functional Use	Water Requirements, mgd (thousand acre-feet)			
	1980	1990	2000	2010
Municipal	232 (260)	308 (346)	389 (436)	484 (543)
Industry-Self Supplied	68 (76)	92 (103)	106 (119)	128 (144)
Steam Electric				
Withdrawals	961 (1078)	983 (1103)	1026 (1151)	1027 (1151)
Consumptive Use	18 (20)	33 (37)	63 (71)	63 (71)
Agriculture	36 (40)	64 (72)	86 (97)	107 (120)
TOTAL	1315 (1474)	1480 (1661)	1670 (1874)	1808 (2029)

water requires conjunctive use or where ground water is exceeding the rate of recharge. The Commission regulates the use of both surface and ground water through the designation of these capacity use areas. Permits are required for allocation within such areas and regulations restricting use may be adopted. Currently, a permit is required from the Commission for withdrawals in excess of 100,000 gallons per day. The Commission may adopt regulations in the designated capacity use areas which: (1) require reports on ground water use, (2) regulate the timing of withdrawals, (3) establish pumping rates, (4) set well spacing boundaries, (5) address salt water abatement, and (6) control new uses which have an adverse affect on existing uses.

The Riparian Doctrine governs water rights. North Carolina has recognized that the Riparian Reasonable Use Doctrine may not be adequate with some of the conflicting demands for water. Accordingly, the North Carolina general assembly has passed several laws which somewhat modify the Riparian Doctrine. For example, the Water Use Act of 1967 required water use permits for large withdrawals as noted above. The Dam Safety Act includes provisions to maintain minimum stream flows for water quality maintenance below some newly constructed dams and the Water Use Reporting Act authorizes the State to request information on water use.

In South Carolina the Water Resources Commission is responsible for establishing a comprehensive water resources policy for the State. Ground water is managed by the Commission through a permit system in designated capacity use areas. Regulations may also be adoped by the Commission in these designated use areas for general management of ground water use. A permit is required from the Commission for ground water withdrawals in excess of 100,000 gallons per day except for domestic uses which are exempt. After designating a

capacity use area, the Commission prepares regulations governing ground water use which include: (1) reporting requirements, (2) timing of withdrawals, (3) well depth and spacing, (4) pumping levels and rates, (5) prevention of salt water intrusion, and (6) mitigation against adverse affects on other users.

The Riparian Doctrine governs water rights in South Carolina. It is recognized by the State that there are certain shortcomings to the Riparian Doctrine including the following:

1. The Riparian Reasonable Use Doctrine does not provide adequate long term security for investments in surface water use.

2. The uncertainty in who may use water and where it must be used under the Riparian Doctrine guarantees future and increasing conflict over water rights.

3. The Riparian Doctrine does not provide adequate protection to the public interest in promoting the best uses of water while protecting the resource.

4. The Riparian Doctrine cannot be employed to establish and protect the best uses of water in times of emergency.

The South Carolina legislature has recognized the need for a revised water law and is currently considering several alternatives. The policies of the legislature require that any system be based on a comprehensive and balanced plan for matching demand with supply and has directed that any such water policy or law:[25]

> (1) provide for the equitable distribution and use of our water, and for the long range development of water resources to their fullest potential, (2) vest in one agency the responsibility of overall State water resources planning and policy making with consideration of water requirements and problems of all water interests, and (3) encompass long range plans for water quality management and all conceivable beneficial uses to which the waters of the State may be put in the foreseeable future.

The Level B Study concluded that a revised South Carolina law should be adopted to achieve the following objectives:[26]

> (1) Provide greater security for beneficial uses of water. To provide such security, an orderly and reasoned system must be developed to account for existing and future uses, to protect beneficial uses, and to provide for the acquisition of new uses.
>
> (2) Provide a sound mechanism to address the rights and value of the territorial limitations presently imposed under riparian law. Where territorial limitations impede the beneficial use of water, they should be lifted; where they bolster the beneficial use of water, they should be applied.

(3) Provide a system to protect public interests in the resource, including provisions to integrate existing requirements for water quality and pollution control.

(4) Provide for allocation of water to the most beneficial uses during emergencies.

The approaches to water law of the two states are fundamentally different although they have some common elements. North Carolina recommends modifications to existing water law while South Carolina recommends a new surface water management law. These differences reflect the existing legal framework, water management practices and public sentiments in the two States.

Water Supply Alternatives

Various water supply problems are anticipated based on the projected requirements shown in Table 16. The Level B Study identified 11 water systems using surface water, and 23 systems using ground water that will need additional capacity by 2010.[28] Table 17 shows that all but one of the surface water systems are in North Carolina.

TABLE 17

WATER SUPPLY SYSTEMS
NEEDING ADDITIONAL CAPACITY
(After U.S. Water Resources Council[28])

Year Treatment System Capacity Exceeded	Number of Systems			
	North Carolina		South Carolina	
	Surface Water	Ground Water	Surface Water	Ground Water
1990	4	4	1	4
2000	2	2	0	5
2010	4	3	0	5

There is no basin wide detailed analysis of projected water shortages with accompanying specific recommendations for increasing water supplies. The Level B Study does describe the systems in Table 17 that will need additional capacity, but specific plans for augmenting the supplies are left to local agencies. The Level B Study presents the following alternatives for further consideration by communities in meeting the projected water supply shortfalls.

- Water Conservation
- Leak Detection and Repair Program
- Additional Use of Ground Water
- Improved Well Design and Construction
- Potential Surface Water Sources
- Purchase from Neighboring Systems
- Regional Systems or Joint Purchasing Agreements

- o Conjunctive Use of Ground Water and Surface Water
- o Conduct feasibility studies of engineering, economic and environmental factors for multi-purpose reservoir projects, with primary emphasis on water supply, for the South Yadkin River, Drowning Creek and the Ararat River.

Water supplies in the Yadkin-Pee Dee basin can be increased through several measures: (1) expand existing supply sources, (2) develop new supply sources of both surface and ground water, and (3) reduce water use through conservation measures. Included under conservation is recycling by industries to reduce the requirements for fresh water withdrawals. The U.S. Water Resources Council Report predicts substantial increases in recycling in the manufacturing industries in this region.

Water Conservation--

Water conservation is now recognized in the Yadkin-Pee Dee Basin as a primary method of effectively increasing water supplies.

- o The North Carolina State Plumbing Code was revised to require the use of water conservation devices in all construction after April, 1980.

- o North Carolina adopted criteria in 1979 to award bonus priority points to clean water bond applicants having local water conservation programs in one or more of three areas: (1) water loss prevention and correction, (2) adoption of the new water conservation sections of the State Plumbing Code, and (3) water conservation, information and educational programs.

- o North Carolina's Office of Water Resources has begun a program to provide technical water planning assistance to local governments. Water conservation practices will be emphasized where feasible, as an alternative when technical assistance is provided through this program.

- o One example of the potential benefits of water conservation is an analysis of 15 municipal systems in the North Carolina portion of the basin conducted during the Level B Study. These 15 systems were projected to have significant deficits by the year 2010. In all cases the effect of reasonable and attainable conservation methods eliminates or greatly delays the onset of the projected deficit. One alternative is the adoption of legislation requiring the use of water conservation devices such as water saving toilets and shower heads in all new or renovated homes and buildings. Another alternative is to grant tax credits for installation of water conservation devices. In this plan, a credit would be given for some percentage of the cost of retrofitting existing structures with approved water conservation devices such as water saving toilets, pressure regulating valves, shower control devices and faucet control devices.

Water conservation as a major water management policy has not been utilized in South Carolina. There are no State-wide programs in South Carolina which encourage the limitation of water use and there are no incentives for

municipal, industrial or agricultural users to conserve water. Conservation measures have not been implemented to date in South Carolina because, historically, there has been an adequate supply of low cost water. However, some areas of South Carolina such as the Grand Strand area of the Pee Dee region have experienced water shortages due to recent population growth.

The Level B Study includes the following recommendation regarding water conservation. This recommendation received a high priority ranking in the North Carolina region of the basin and a medium priority in South Carolina.[26]

Local government, which is most directly responsible for planning and managing water supply systems, should take the following actions:

- Every utility should begin a program of customer education to encourage conservation. Ideas include mailings and brochures, radio and television public service announcements, publication of daily water use data in local newspapers, and provision of conservation devices like flow restrictors and toilet tank inserts to customers.

- Some water utilities should consider rate schedule revisions to encourage conservation after careful study of their system's needs and customer mix. The ideal should be equitable apportionment of the actual costs of water to all users.

- Water utilities should provide better operation and maintenance of their systems. Programs of leak-detection and repair should be developed and all water supply systems should be metered. Many unmetered systems (e.g., most mobile home parks) use excessive amounts of water. Meter repair programs should also be followed by all communities.

- Local ordinances should be developed to require water conservation devices using building and/or plumbing codes, as well as emergency use restrictions during system failures, supply disruptions or droughts. In the future, it may be desirble to provide local incentives for water conservation in specific locations facing excessive demands on the existing water supply system.

At the State level, North and South Carolina should take the following steps:

- Water conservation education programs should be developed by NCOWR and NCDHR and by SCDHEC and SCWRC. Each program should consist of two parts - the first directed toward water supply system managers and personnel. Training in leak detection techniques and water conservation methods should be emphasized. The second part should be directed toward the general public. Brochures and pamphlets on conservation benefits and methods should be developed by NCOWR through its newly developed water supply assistance program. Such resource materials could then be made available to local water

suppliers along with technical assitance in setting up local water conservation programs. SCDHEC and SCWRC should develop similar programs in South Carolina.

- The States should fund special demonstration projects on water conservation. Potentially valuable topics to include in such demonstrations would be water reuse, the impact of water conserving devices on energy costs to homeowners and industries, dual water systems and impacts of water rate revisions and conservation programs on utility revenues.

- South Carolina should pass legislation similar to North Carolina requiring water conserving devices on all new construction.

- Both States should develop model conservation/emergency water use ordinances and encourage their adoption by local units of government. Such legislation should formally declare a State policy encourging water conservation.

- The States should encourge the recruitment and development of water efficient industries within the Yadkin-Pee Dee River Basin.

- Water conservation improvements at State-owned facilities should be implemented.

At the Federal level, the following actions should be taken:

- An evaluation should be conducted by USWRC to eliminate inconsistent Federal policies and fulfill the National water policy initiatives on water conservation. Particular attention should be given to incorporating water conservation as a criterion in FMHA funding of water supplies.

- The Federal government should examine the feasibility of offering tax incentives, particularly to industry, for water conservation.

- Water conservation improvements at Federally-owned facilities should be implemented.

In addition to this recommendation on water conservation, the Level B Study presents a high priority recommendation for North Carolina to develop a model drought contingency plan and emergency water conservation ordinance for use by municipal systems. Another recommendation in the Level B Study is to establish a method to allocate water and protect the most beneficial uses during water shortage emergencies in South Carolina.

Water Quality

A comprehensive review of water quality in the Basin was conducted for the 1974-78 period during the Level B Study. All Stored data for active primary and secondary stations within the Basin was reviewed for: (1)

dissolved oxygen, (2) biochemical oxygen demand, (3) total kjeldahl nitrogen, (4) nitrate and nitrite nitrogen, (5) total phosphorus, and (6) coliform bacteria.[24]

Based on a review of this data it was concluded that the most severe potential point source problems were in the smaller drainage areas. High coliform bacteria counts, low dissolved oxygen and high nitrogen and phosphorus concentrations were the problems observed. These problems are caused by a relatively large number of point source discharges located within small drainage areas. Point source related pollution problems were not as evident in the larger streams, however the Great Pee Dee and Lynches River drainage areas did contain high coliform levels.

The parameter which most frequently exceeded planning criteria was fecal coliform bacteria followed by dissolved oxygen, total phosphorus, biochemical oxygen demand, nitrate and nitrite nitrogen and total kjeldahl nitrogen. These pollutants are indicative of organic matter characteristically present in municipal and industrial discharges. In addition to the problems noted with the point source discharges there were potential nonpoint source problem areas, the majority of which are within the coastal plain.

Point source discharges within the Yadkin-Pee Dee Basin include municipal, industrial and private domestic. All major industrial discharges are in compliance with their permits, but some toxic materials are still discharged to surface waters because permits generally consider only conventional pollutants such as biochemical oxygen demand and coliform bacteria. However, with the implementation of the Best Available Technology provisions of the Clean Water Act, the discharge of toxic materials should be significantly reduced. There are several major municipal discharges which are not in compliance with permit limitations because of the need for construction of additional treatment facilities. The required facilities are all scheduled to be completed by July, 1983, although achievement of this goal is doubtful.

The Level B Study includes the following water quality recommendations that fall in three major categories: (1) those designed to improve the understanding of specific water quality problems, (2) those dealing with new or improved water quality programs and, (3) those dealing with water quality standards.

- Revise water quality monitoring programs in both States.
- Conduct study of High Rock Lake eutrophication.
- Complete Brunswick County shellfish study.
- Conduct study of agricultural nonpoint source problem areas in South Carolina.
- Enact Sediment Erosion Control Act in South Carolina and improve existing program in North Carolina.
- Develop local programs to control urban stormwater runoff.

- Increase State role in water quality management.
- Implement voluntary program to control agricultural nonpoint source pollution.
- Concentrate agricultural nonpoint source control measures in high priority North Carolina watersheds.
- Reclassify Big Shoe Heel Creek and Bridge Creek in North Carolina.
- Change North Carolina effluent standards on controlled streams.
- Enact ground water quality standards in South Carolina and classify aquifers in both States.

SECTION 5

ISSUES, TRENDS AND RESEARCH NEEDS

Information on major issues, trends and research needs in water availability for this study were collected from several sources including:

1. Recent reports and reviews on the National water situation including comments and critiques on Federal water policy and research activities.

2. Regional reports, many of which were prepared under the Federal Water Resources Planning Act.

3. Reports by various State agencies.

4. Discussions with local water agency personnel and others during the work on this project.

5. Informal discussions with knowledgeable persons in Washington, D.C. to solicit opinions on major issues, trends and research needs in water availability.

NATIONAL PERSPECTIVE

There are several recent reports on National water issues and problems. A report by the General Accounting Office concludes that the Nation faces serious water problems in the West and certain other areas of the country.[6] The GAO report states that water related research and development activities are fragmented among 28 Federal organizations and that congressional action is needed to better focus the use of Federal funds. The GAO report further concludes that a comparative assessment of conservation and augmentation technologies is needed to establish water research priorities and allocate research funds.

The U.S. Water Resources Council has published two recent reports that review water resources trends and issues.[7,29] These reports also summarize the State statutes, policies and regulations that deal with comprehensive water resources planning and management. The WRC reports conclude that virtually every State and region in the Nation is experiencing a range of water resources problems. The most frequently noted problems are: (1) overdraft of ground water caused by increasing demand for irrigation or by population growth coupled with inadequate supplies of surface water, (2) erosion and sedimentation of river banks and other lands and (3) flooding.

The National Academy of Sciences, National Research Council studied the 1975 assessment of the Nations water resources by the U.S. Water Resources Council and other reports and developed criteria to determine the priority of water resources research.[30] The Research Council identified 31 research areas where emphasis should be placed in programming research over the next five years. The 31 research areas were grouped into ten problem areas. Two of the problem areas are ground water quantity and quality and water conservation.

A recent study by the Congressional Research Service for the Senate Committee on Environment and Public Works considered the value and usefulness of the assessments of the Nations' water supplies prepared by the Water Resources council.[31] The Congressional Research Service interviewed professionals in 16 Federal agencies and experts from universities, congressional staffs, State agencies, and water resources consulting firms. The report criticizes some of the Water Resources Council methods in preparing and presenting the National water assessments but concludes that "There is widespread and general agreement that a meaningful, continuous water assessment and appraisal program would have merit if properly designed. Such a program could keep priorities current; update the problem identification and analysis components; track the effectiveness of existing programs in addressing major water issues; and provide in-depth analyses of specific problems."

A recent review of National water policy notes that since the early 1900's over 20 commissions or committees have worked to identify water problems, evaluate the availability of water and consider new directions in water policy.[32] It is concluded that the most controversial policy issues have defied effective remedial action and that perhaps direct congressional intervention is needed to provide a forum with adequate power to generate the needed water policy reform.

REGIONAL PERSPECTIVES

There has been some criticism of the national water policy that connotes a uniform policy and program applied to all regions of the United States. For example, a policy that requires water conservation and reuse on a National scale may not be reasonable for all areas. A uniform approach minimizes the diversity of water resources and problems in the Nation while attempting to apply one program to all regions. The Second National Assessment identifies water problems including poor quality and inadequate supply but the problems are drawn along regional lines.[1]

The major water and related resource problems and issues of the Western States are in general common to all 11 States, differing only in the extent or degree of seriousness.[4] The Westwide Study grouped the problems and issues into four broad categories: water supply, water quality, environmental and other. There are large areas in the West such as the Upper Rio Grande and the Gila River basins where the total annual surface water supply is completely consumed. In the Colorado River basin this condition will be reached when the Central Arizona Project is completed. Water supply problems in the West include: water for energy resources development, water for small communities,

water for Indian reservations, water for public lands, water from conservation and reuse and water from weather modification. Related water quality problems include: water pollution and urban waste management, increasing salinity in major river systems and erosion and sedimentation.

A major study sponsored by the Environmental Protection Agency assesses the relationship between water resources and energy development in eight Western States.[6] The study has two general purposes:

- To identify the most important water impacts and issues likely to be associated with energy development; and
- To idenfity and evaluate policy alternatives for dealing with problems and issues.

The report concludes that energy development will create several impacts on Western water resources. The nature and severity of the impacts will depend on the technologies chosen to develop resources and the locations where they are sited. Among the most important factors are:

- The type and number of facilities;
- The cooling technologies;
- Effluents produced by the facilities;
- Water availability region-wide and at specific development locations; and
- The location and depth of aquifers in relation to mining.

Many of the conflicts over water availability and quality discussed in the report will exist even without energy development because the region is generally water-short and because a variety of demands are being made for the use and protection of the resource. Not only will energy development aggravate these issues but they, in turn, can directly influence energy resource development decisions.

The report also includes a comparison of findings with two other recent reports which address the relationship between energy development and water resources in the West, one by the Colorado Department of Natural Resources (1979, for the U.S. Water Resources Council) and one by the General Accounting Office.

An earlier summary report on all aspects of energy development in the West concludes that energy development, particularly electric power generation using wet cooling methods, will add to current water availability problems and intensify existing political conflicts regarding water resource management.[33] The report also concludes that water quality will become an increasing concern as energy resources are developed in the eight State study area of Montana, Wyoming, North Dakota, South Dakota, Utah, Colorado, Arizona and New Mexico. Specific problems and issues identified in the summary report are:

- Water shortages in the Colorado River basin.

- Energy requirements for water added to non energy requirements exceed the minimum available estimates by as much as 1,000,000 acre-feet in the year 2000.

- Increasing conflicts in the Upper Missouri River basin. Unsettled water rights in the Yellowstone River and increased demands from Indian, energy, agriculturial and environmental interests have created considerable uncertainty over how the remaining supplies will be used.

- Indian water rights. There are legal and political problems involving the reserved water rights of Indians.

- Irrigated agriculture. Extensive development of energy resources would compete with existing agricultural irrigation use.

The Columbia River is the major water resource feature in the Pacific Northwest but there are three other major river basins that are important to the regions' water resources development.[34] Although in an average year the Columbia River produces more than 10 times the flow in the Colorado River, during the drought of 1977 the flow was not adequate for all demands. The three major competing uses in the Columbia River basin are power generation, irrigated agriculture and instream flow requirements for fish, navigation, recreation and water quality protection. Allocation among the competing uses is complicated by the water rights situation. There are uncertainties created by Indian claims to water and by claims associated with Federal lands. One of the high priority actions recommended in this region is to determine the legal availability of water at key locations, and particularly to resolve the uncertainties regarding: (1) Indian reserved water, (2) Federal reserved water, (3) unadjudicated water, (4) unused water rights, and (5) actual water use.

The first and the top priority of the basinwide conclusions in the Missouri River Basin Water Resources Management Plan concerns water rights associated with Indian and Federal lands.[35] The basin plan concludes that there is a serious problem affecting most of the Missouri basin States, and many of their water resources management programs, regarding the uncertainty surrounding Indian water rights, and the rights associated with Federal lands. Agriculture is the predominate industry in the Missouri River basin and Federal irrigation programs are very important to this area. Another important issue in the Missouri River basin is the limited and poor quality water supplies in many rural areas. There is also a growing concern for water quality issues in general. Many of the water quality problems arise from nonpoint sources, mainly runoff from farms and range lands.

The major problems identified in the Arkansas-White-Red River Basins were: (1) inadequate ground and surface water supplies, (2) degraded surface water quality and (3) flooding of related lands.[36] Every State in this basin identified inadequate surface and/or ground water supplies as a significant problem. Surface and ground water supply shortages are common

throughout the region. The shortages affect large and small communities and uses ranging from lack of storage for surface supplies to a lack of conveyance and treatment facilities for existing surface impoundments. Ground water problems include depletion of existing supplies, lack of information regarding new supplies and lack of financial capability to develop known sources.

The water policy issues in the Ohio River basin include mine drainage, nonpoint source pollution and instream flows.[37] In general, there is adequate water in the Ohio River basin to meet the anticipated demands; however, the projections of consumptive use in some of the tributaries are close to the 7-day, 10-year flow. Potential solutions include management of water use and building additional reservoirs to conserve water during high flow periods so it will be available during periods of drought. Water supply and energy and water quality are issues in the Allegheny River basin which is a tributary to the Ohio River.[38] Water supply issues in this basin include the need to rehabilitate urban and rural water systems and consumptive use and instream flow needs. The basin plan recommends a water conservation program which integrates supply and demand considerations. Water quality issues include ground water pollution from inactive coal mines, oil and gas wells and sludge disposal, the assessment of pollution from toxic and hazardous substances and the assessment of nonpoint sources of pollution.

A recent report presents recommended priorities for Federal investment in water related activities in the New England-New York region.[39] The following problems and issues are considered to be of regional and even national significance and appropriate for Federal involvement:

- Impacts of acid rain on water and fisheries.
- Effects of toxic and hazardous wastes on ground and surface waters.
- Water supply related needs caused by deteriorating infrastructures, requirements of the Safe Drinking Water Act and the current drought.

There are several water resources management and water supply issues in the Hudson River basin.[40] Present quantities of water are generally considered sufficient to the year 2000 although there are deficits projected for some local areas. A shortage of 400 mgd is currently estimated for the lower Hudson basin area which will require complicated institutional and financial arrangements to solve. The basin plan recommends a conservation policy oriented toward improving public water supply systems. Municipal water demands within the basin are expected to increase from 302 mgd to 398 mgd by the year 2000.

The Thames River basin located in the Eastern third of Connecticut with small head water areas extending into Massachusetts and Rhode Island is one of the most rural basins in New England with over 90 percent of its area in open space.[41] The major water related issues in this basin are pollution abatement and water quality maintenance, water supply development and source protection. Poor water quality is a particularly severe problem in the North-Eastern part of the basin. The basin plan concludes that maintaining clean water will depend upon further funding and development of State and Federal

programs for wastewater management for nonpoint source pollution control and for management of residual toxic wastes. As many as 13 towns in the Thames River basin will need water supply development by 1990. There is sufficient water in the basin to meet these requirements but no regulatory mechanism to protect the watersheds and aquifers from nonpoint source pollution.

OPINIONS ON MAJOR ISSUES, TRENDS AND RESEARCH NEEDS

Informal discussions on major issues, trends and research needs were conducted with 12 persons knowledgeable in water matters including staff members of congress, the administration, and organizations which advise them. During these discussions opinions were solicited on the following questions.

1. Are the Water Resources Council predictions of inadequate streamflows in 2000 in the Central and Southern plains, the Southwest, and the Virgin Islands still valid?

2. Are there any important emerging trends or breakthroughs that will alter the avilability of water? What about reuse, desalting, conservation, or use for energy?

3. Have any major issues, conflicts, or problems relating to water availability emerged in recent years? What about water rights?

4. What environmental problems do you foresee relating to the availability of water?

5. What research would be most helpful in resolving problems of water availability?

The discussions were informal and not limited to these questions. Many of the individuals were working on specific projects relating to research, legislation, guidelines for planning, and organizational changes. These inevitably came up as the questions were being discussed.

In the following summary of the discussions, the comments are grouped as they relate to the five general questions. Individuals comments are not identified.

QUESTION 1. Are the Water Resources Council predictions of inadequate streamflows in 2000 in the Central and Southern plains, the Southwest, and the Virgin Island still valid?

The general response to this question was that there was no reason to doubt the findings of the Water Resources Council. No investigations have been made subsequently which would cast doubt upon the findings or projections of water shortages. One of those interviewed states that future consumption of water will be greater than predicted by the Council. He said that the Council's favorable predictions of increased irrigation efficiency and increased recycling of industrial water were overly optimistic. However, he and several others stated that the real problem is not one of actual water shortages but rather one of managing existing supplies.

A few of those questioned thought that the Council did not give sufficient emphasis to the water supply problems of the Eastern United States. Droughts will have a serious impact on highly populated areas in the East that do not have sufficient reserve capacity in their water supply systems. Northern New Jersey, New York, and Southeastern Virginia were mentioned as problem areas. If the Assessment had highlighted the critical monthly water shortages indicated by the water data it could have alerted the Eastern cities to the potential shortages which some have since experienced.

The Water Resources Council Assesment data were for 106 subregions of the Nation. Subsequent studies have been made which identify many specific locations with water supply problems. The Office of Water Research and Technology report on the Evaluation of Potential Sites for Desalting Demonstration Plants, December 1978, identifies 37 sites with water quantity or quality problems, or both. The report states that all of these locations have problems which could be effectively overcome with desalting technology.

QUESTION 2. Are there any important emerging trends or breakthroughs that will alter the availability of water? What about reuse, desalting, conservation or use for energy?

The response of most persons to this question was very favorable. The respondents generally thought that the water supply situation had improved. Many factors were cited but the principal one was the easing of the pressure to develop the coal and oil shale deposits of the West. There is less push for the development of synfuels. The competition between energy and agriculture for Western water is not developing as fast as predicted by many. The amounts of water needed for energy are very site specific and not large in the aggregate. There is more efficiency in the use of water. Conservation is increasing at the State and local level. Some Federal water projects require conservation considerations as a part of the project agreement with water users. There will be more use of brackish water and water reuse will increase. There is also a movement to teach improved water management. These water saving steps are occurring because there is a trend toward increased cost sharing by users, more realistic pricing of water, and more information being provided the public concerning droughts and water supplies. The effect on water supplies may not be large but it is a reversal of past trends and eases the need to develop more water supplies.

Others said desalting is expanding but is not a major contributor to the Nation's water supplies. Conservation is not being given official emphasis that it once had at the Federal level. The use of water banks to shift water to areas of need was under consideration in several States but not much has been heard of these proposals lately.

One person said that there will not be any major breakthroughs in desalting, reuse, or conservation unless more effort is made to support research in these areas. Several said that there would be no major Federal water supply projects in the near future. The future Federal water expenditures will be in the rehabilitation of existing Federal projects.

QUESTION 3. Have any major issues, conflicts, or problems relating to water availability emerged in recent years? What about water rights?

The responses indicated a variety of water supply problems. These problems tended to be site specific rather than widespread. Ground water use may be restricted because of pollution. Salinity of water supplies is a continuing problem in the West. Sources of ground water pollution are difficult to identify. Surface water pollution is also a problem. Lowering ground water levels are restricting supplies in some areas.

Several persons mentioned the problem of financing water projects as being basic and pervasive. The problem is that there is less and less Federal money available - less for research - less for projects. There is a lack of willingness to pay for needed water projects or water research. There is a lack of public or institutional response to water problems. Increased local cost sharing and requirements for up-front money for Federal reservoir projects will impact on water development. States with adequate funds will come up with the money or proceed without Federal assistance while poorer States will defer needed water projects. States will take the lead in resolving the water problems of the future.

The role of the Federal government in water development is at issue. While assistance has been given to water development in the Western States the major Eastern cities have water supply systems which are falling apart because of a lack of maintenance. This is a severe National problem. The necessary rehabilitation of these systems will cost on the order of 20-30 billion dollars. Where is this money coming from? What is the Federal interest in city water supply systems?

One person said that the big problem is that we have an institutional morass. The efficient management of the water resources is hampered by existing laws, rules, traditions, organizations, politics, and customs.

Several commented that progress is being made with respect to State-Federal-Indian water rights but it is a long slow process. It will probably be worked out by agreement of the interested parties and/or legislation. The ultimate effect on water supplies is difficult to determine at this time.

QUESTION 4. What environmental problems do you foresee relating to the availability of water?

The responses to this question fell into two broad categories. One category concerns the environmental impact of water supply storage facilities. The other category concerns the quality of water supplies.

The environmental situation with respect to water projects is improving. Federal and State agencies are doing a better job of planning to avoid detrimental environmental impacts. Developers of storage projects must still consider the impacts of reduced streamflow on downstream fish and wildlife. Debris from development is also a hazard. Reservoir releases can destroy downsream habitat for fish and wildlife. Water storage projects flood farm land and desirable stream segments. The key to avoiding environmental problems is to identify them early in the plannng process.

Most of those interviewed said that the major environmental problem relating to water availability is water quality. Pollution of ground and surface water is occurring from landfills, industrial waste dumps, and nonpoint sources. Synthetic organics in water supplies are a serious problem. Salt from irrigation development and natural sources is a problem in Western water supplies. The increased use of brackish water will save fresh water but creates a problem with respect to the disposal of the concentrated salts. The quality of water in the estuaries is a problem for the large coastal cities.

QUESTION 5. What research would be most helpful in resolving problems of water availability?

The bulk of the responses to this question concern either water quality or the institutional arrangements for managing the Nation's water supply systems. Several persons referred to recent efforts by the Office of Water Resources Research and the National Research Council to identify needed water resources research.

One comment suggested the continued research into ways of controlling salinity entering our fresh water streams. Another suggested more analysis of the use of vegetative cover to improve runoff into streams and reservoirs. More research on the use of water in energy related industrial processes was also suggested. Studies of the effects of sudden population growth on remote areas of the West would help avert problems in the future. Research on the characteristics of ground water reservoirs is needed. More work on desalting and water reuse was suggested.

There were many suggestions concerning water quality studies. These included the need to develop more efficient and faster moitoring systems to detect toxics and other pollutants in water supply systems. An analysis of the quality of water currently being provided by the Nation's water supply systems should be made. What are the long term health effects of the contaminants in water supplies? What are the synergistic effects of stream and ground water pollutants? Innovative ways to monitor water supplies should be investigated. An example of such monitoring is the use of live fish to determine the presence of harmful but undetected substances in the water. Research is needed to determine how the pollution of water effects the ecosystem and how this effects the survival of man.

The capability of water supply plant operators should be studied. Large investments are wasted if plants are not operated correctly. Methods of improved operator training should be examined.

Methods of treating contaminated ground water aquifers should be tested. Desalting and treatment of estuary water should be studied. How can waste disposal and landfill areas be cleaned up or contained to protect ground and surface water supplies?

The instream flows necessary to sustain fish and wildlife should be determined.

How can the management of water be improved? Better ways to regulate water use and protect its quality should be found. What is the role of user charges and effluent charges? There should be a research infrastructure leading to a broad look at water problems rather than the current individual research efforts oriented to the support of specific programs. Efforts should be made to improve the National asessment of water supply and demand. We need to take a new look at water rights transfers. Institutional alternatives for managing the water supplies should be analyzed. We should determine the benefits and costs to various groups within society through the use of different water management arrangements. A basin by basin analysis of water management arrangements similar to that recently done for the Potomac should be accomplished for other basins. It should be an interagency intergovernmental objective analysis.

One individual stated that institutions exist for regulating surface water and planning for its use but the same cannot be said for ground water. Ground water and surface water are interconnected and need to be considered together. Studies are needed to identify appropriate institutions for the development and protection of ground water. Steps need to be taken to promote the conjunctive use of ground and surface water and to provide regional consideration of interrelationships. What is the National interest in ground water? Analysis of the effectiveness of the Delaware and Susquehanna River Basin Commissions would be a good place to start.

CONCLUSIONS

The following conclusions are based on the investigations conducted for this report.

1. There are water availability and water quality problems in many regions in the United States. However, the problems are regional and local in nature and there are few common issues, problems and research needs for the entire Nation.

2. The three detailed studies of water sensitive regions presented in this report illustrate the regional nature of the issues, problems and research needs.

   - San Antonio, Texas is a large city surrounded by farms and ranches that derives most of its water from ground water. Substantial population growth is projected for this area and future water requirements can be met with additional development of surface water supplies and conjunctive use of ground water and surface water sources. Good management and the proper institutional arrangements will be required to insure that the limited water supplies are adequate for future needs.

   - Southern California must now develop and augment local supplies since through a recent Statewide referendum it was decided not to construct additional large scale surface water transfer projects. Alternatives for supplying future requirements in Southern California include conservation, large scale wastewater reuse,

desalination and continuing conjunctive use. A major deterrent to development of additional wastewater reuse projects is the disparity in the cost of power for wastewater reuse and water import projects. Currently, surface water import projects receive substantial power rate subsidies.

- o The Yadkin-Pee Dee Basin in North Carolina and South Carolina has adequate water supplies to meet future needs. Potential problems in this basin can be mitigated with additional development of surface water supplies coupled with institutional arrangements for management.

3. The problems caused by uncertainty of water rights on Indian and Federal lands is widespread in the Western United States. The water rights situation is specifically mentioned in several Western basin plans as a major deterrent to development and allocation of water resources.

4. The most widespread problem in the Nation is limited water supply quantity. The immediate and most achievable methods of augmenting water supplies at almost all locations includes the following:

   - o Conservation procedures such as lowering water use in residences and in farming operations and emergency plans for water use curtailment and conservation during periods of drought.

   - o Wastewater reuse offers the potential for augmenting supplies in many locations. Potential uses of reclaimed water include agricultural irrigation, landscape irrigation, industrial processing and cooling water, and ground water recharge.

   - o Conjunctive use of ground water and surface water supplies in areas where ground water is available.

   - o Desalination technology is available to furnish high quality water from saline and brackish water and may be cost-effective in some areas.

   Other methods such as weather modification and evaporation reduction may augment supplies in the future but technology is not sufficiently developed for immediate use.

5. Research needs are also somewhat regionalized. For example, the following research priorities were recommended for New Mexico based on a survey of water users.[42]

Research Need	Percentage of Total Sample Indicating this Topic as a Priority Item
Utilization of Saline Water	43
Improved Irrigation Management	32
Drinking Water Quality	31
Ground Water Surveys	29
Water Use Allocation	26
Equitability of Water Rights	18
Water Conservation	16
Energy Development Impacts	10
Water Reuse	5
Desalination	3
Nonpoint Source Pollution	3

6. Research activities applicable to the Nation in general should be focused on areas with the highest potential for major water supply augmentation.

   - Conservation - Many regions throughout the Nation, from East to West, have cited the importance of conservation and its potential for augmenting supplies. Conservation is important for augmentation of both agricultural and municipal supplies.

   - Wastewater Reuse and Recycling - Many water short regions of the Nation can augment their supplies by reusing municipal wastewater and recycling industrial water.

   - Many of the basin plans and reports and the persons contacted during this study cited the need for improvement in water rights and institutional arrangements for more efficient use and allocation of supplies. The water rights issues on Federal and Indian lands should be settled so that water development and allocation can proceed.

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